JUN [illegible]

C55.622: 981/v.9

COMPLETED
785

ORIGINAL

Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators

Volume 9. Biological Studies

U.S. DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
Office of Marine Pollution Assessment

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

April 1981

BEST DOCUMENT AVAILABLE

Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators

Volume 9. Biological Studies

U.S. DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
Office of Marine Pollution Assessment

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

April 1981

I

The facts, conclusions and issues appearing in these reports are based on interim results of an Alaskan environmental studies program managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and primarily funded by the Bureau of Land Management (BLM), U.S. Department of Interior, through interagency agreement.

DISCLAIMER

Mention of a commercial company or product does not constitute an endorsement by National Oceanic and Atmospheric Administration. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

TABLE OF CONTENTS

Volume 9: Biological Studies

RU#	PI/Agency	Title	Page
005	Feder, H.M. and S.C. Jewett -University of Alaska, Fairbanks, AK	Distribution, Abundance, Community Structure and Trophic Relationships of the Nearshore Benthos of the Kodiak Continental Shelf	001
005	Feder, H.M. K. Haflinger, M. Hoberg and J. McDonald -University of Alaska, Fairbanks, AK	The Infaunal Invertebrates of the Southeastern Bering Sea	257

FINAL REPORT

Contract: #03-5-022-56
Task Order: #15
Research Unit: #5
Reporting Period: 3/78-3/80
Number of Pages: 244

DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE AND TROPHIC RELATIONSHIPS OF THE NEARSHORE BENTHOS OF THE KODIAK CONTINENTAL SHELF

Howard M. Feder
Principal Investigator

with

Stephen C. Jewett

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

March 1980

ACKNOWLEDGEMENTS

We would like to thank the officers and crew of the NOAA Ship *Miller Freeman*, the R/V *Commando*, and the M/V *Yankee Clipper* for their assistance in data collection. Thanks also go to the Alaska Department of Fish & Game (ADF&G) and Fisheries Research Institute (FRI) personnel for their assistance onboard ship. A special acknowledgement goes to Guy C. Powell of ADF&G Kodiak for his assistance in the collection of king crabs *via* SCUBA. We would also like to thank the following Institute of Marine Science, University of Alaska, personnel: Max Hoberg, Kristy McCumby, Camille Stevens, John Rose and Steven McGee for shipboard and/or laboratory assistance; Cydney Hansen and Robert Sutherland for assistance and in data processing and statistical analyses; and Helen Stockholm, Suzette Carlson, Ana Lea Vincent and the IMS Publication Staff for aid in preparation of this report.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS. 2

LIST OF FIGURES 6

LIST OF TABLES. 7

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT. 12

II. INTRODUCTION. 15
  - General Nature and Scope of Study 15
  - Relevance to Problems of Petroleum Development. 17

III. CURRENT STATE OF KNOWLEDGE. 19

IV. STUDY AREA. 22

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION 22

VI. RESULTS 33
  - Trawl Data: Distribution-Biomass 33
    - Izhut Bay. 33
    - Kiliuda Bay. 44
    - Kodiak Shelf 48
  - Pipe Dredge Data: Distribution-Relative Abundance. 54
    - Kodiak Shelf 54
  - Sediment Sweep Data: Relative Abundance. 58
    - Near Island Basin. 58
  - Reproductive Data: King Crab and Snow Crab 58
  - Food Studies. 60
    - *Paralithodes camtschatica* (King Crab). 60
      - Izhut Bay 60
      - Kiliuda Bay 63
      - Near Island Basin 73
      - McLinn Island 77
      - Anton Larsen Bay - Site 1 83
      - Anton Larsen Bay - Site 2 83
      - Kodiak Shelf. 86
    - Statistical Analysis - King Crab 89
      - King crab food *versus* sex 89
      - King crab food *versus* size. 93
      - King crab food *versus* crab class. 93
      - King crab food *versus* sampling period 98
      - King crab food *versus* sampling area 98
      - King crab food *versus* depth 102

BEST DOCUMENT AVAILABLE

TABLE OF CONTENTS (Continued)

- *Chionoecetes bairdi* (Snow Crab). 102
  - Izhut Bay 102
  - Kiliuda Bay 115
  - Kodiak Shelf. 125
  - Near Island Basin 129
- Statistical Analysis 132
  - Snow crab food *versus* crab size 132
  - Snow crab food *versus* crab class. 132
  - Snow crab food *versus* sampling period 138
  - Snow crab food *versus* sampling area 138
  - Snow crab food *versus* depth 138
- *Pandalus borealis* (Pink Shrimp). 138
- *Pycnopodia helianthoides* (Sunflower Sea Star). 147
- *Gadus macrocephalus* (Pacific Cod). 147
  - Izhut Bay 147
  - Kodiak Shelf - June-July 1978 147
  - Kiliuda Bay - August 1978 151
  - Kodiak Shelf - February 1979. 151
- *Hemilepidotus jordani* (Yellow Irish Lord). 151
  - Kodiak Shelf - March 1978 151
  - Kodiak Shelf - June-July 1978 151
  - Kodiak Shelf - February 1979. 162
- *Myoxocephalus* sp. (Sculpins) 162
  - Izhut Bay - May 1978. 162
  - Kodiak Shelf - June-July 1978 162
  - Kodiak Shelf - Febryary 1979. 162
- *Hippoglossoides elassodon* (Flathead Sole). 163
  - Kodiak Shelf - June-July 1978 163
  - Kodiak Shelf - Febryary 1979. 163
- *Lepidopsetta bilineata* (Rock Sole) 163
  - Izhut Bay - May 1978. 163
  - Kodiak Shelf - June-July 1978 163
  - Kodiak Shelf - February 1979. 163
- *Pleurogrammus monopterigius* (Atka Mackerel). 164
  - Kodiak Shelf - June-July 1978). 164
- *Atheresthes stomias* (Arrowtooth Flounder). 164
  - Kodiak Shelf - June-July 1978 164
- *Anaplopoma fimbria* (Sablefish) 164
  - Kodiak Shelf - June-July 1978 164
- *Theragra chalcogramma* (Walleye Pollock). 164
  - Kiliuda Bay - August 1978 164
- *Limanda aspera* (Yellowfin Sole). 164
  - Kodiak Shelf - February 1979. 164
- *Isopsetta isolepis* (Butter Sole) 166
  - Kodiak Shelf - February 1979. 166

TABLE OF CONTENTS (Continued)

VII. DISCUSSION 165

Trawl Data: Distribution-Biomass 165
- *Paralithodes camtschatica* (King Crab). 165
- *Chionoecetes bairdi* (Snow Crab). 167
- *Pandalus borealis* (Pink Shrimp). 168
- Asteroidea (Sea Stars) 169

Food Studies. 170
- *Paralithodes camtschatica* (King Crab). 170
- *Chionoecetes* spp. (Snow Crabs) 177
- *Pandalus borealis* (Pink Shrimp). 181
- *Pycnopodia helianthoides* (Sunflower Sea Star). 182
- *Gadus macrocephalus* (Pacific Cod). 183
- *Myoxocephalus* spp. and *Hemilepidotus jordani* (Sculpins). 184
- *Hippoglossoides elassodon* (Flathead Sole). 184
- *Lepidopsetta bilineata* (Rock Sole) 185
- *Atheresthes stomias* (Arrowtooth Flounder). 185
- *Pleurogrammus monopterigius* (Atka Mackerel). 186
- *Anaplopoma fimbria* (Sablefish) 186
- *Theragra chalcogramma* (Walleye Pollock). 186
- *Limanda aspera* (Yellowfin Sole). 187
- *Isopsetta isolepis* (Butter Sole) 188

VIII. CONCLUSIONS. 188

IX. NEEDS FOR FURTHER STUDY. 190

X. REFERENCES 192

XI. APPENDICES 200

Appendix A - Benthic Trawl and SCUBA Stations Occupied in the Kodiak Region, 1978-79. 200

Appendix B - Table I - Intestine Contents of King Crabs from the Kodiak Island Region, 1978 204

Appendix B - Table II - Stomach Contents of Snow Crab ≤ 40 mm Carapace Width from the Kodiak Island Region, 1978-79. 220

Appendix C - Summer Food of the Pacific Cod, *Gadus macrocephalus*, Near Kodiak Island, Alaska 230

Appendix D - Summer Food of the Sculpins, *Myoxocephalus* spp. and *Hemilepidotus jordani*, Near Kodiak Island, Alaska. 238

LIST OF FIGURES

Figure 1. Benthic trawl stations occupied in Izhut Bay, Afognak Island, 1978-79. The bay is divided into three areas which are referred to in the text. 23

Figure 2. Benthic trawl stations occupied in Kiliuda Bay, Kodiak Island, 1978-79. The bay is divided into four areas which are referred to in the text. 24

Figure 3. Locations where king crabs were collected *via* SCUBA for stomach analysis, 1978-79. 25

Figure 4. Benthic trawl stations occupied in March, 1978 26

Figure 5. Benthic stations occupied in June-July 1978 and February 1979. 27

LIST OF TABLES

Table I. The number of stomachs from each predator examined by sampling area and collection period. 29

Table II. The number of crab stomachs examined by sampling area and collection period. 30

Table III. Trawl stations occupied in Izhut and Kiliuda Bay, 1978-79, and stations where large numbers of king crabs, snow crabs and/or pink shrimp were collected 34

Table IV. Summary of trawl activities from Izhut and Kiliuda Bays, 1978. 35

Table V. Percent biomass composition of the invertebrate phyla of Izhut and Kiliuda Bays, 1978-79. 36

Table VI. Percent biomass composition of the invertebrate families of Izhut and Kiliuda Bays, 1978-79 37

Table VII. Percent biomass composition of the invertebrates of Izhut and Kiliuda Bays, 1978-79. 38

Table VIII. Invertebrates taken by trawl in Izhut Bay, 1978-79 39

Table IX. Invertebrates taken by trawl in Kiliuda Bay, 1978-79 45

Table X. Percent biomass composition of the leading invertebrate species collected on the Kodiak shelf. . . . 49

Table XI. Invertebrates taken by trawl on the Kodiak shelf, 1978-79 51

Table XII. Dominant taxa by station collected *via* pipe dredge on the Kodiak shelf. 55

Table XIII. Organisms collected in Near Island Basin *via* sediment sweep. 59

Table XIV. Numbers and locations of king crabs examined for food contents 61

Table XV. Stomach contents of king crabs collected *via* trawls in Izhut Bay - June 1978 62

Table XVI. Stomach contents of king crabs collected *via* trawls in Izhut Bay - July 1978 64

LIST OF TABLES (Continued)

Table XVII. Stomach contents of king crabs collected *via* trawls in Kiliuda Bay - April 1978. 65

Table XVIII. Stomach contents of king crabs collected *via* trawls in Kiliuda Bay - June 1978 66

Table XIX. Stomach contents of king crabs collected *via* trawls in Kiliuda Bay - July 1978 68

Table XX. Stomach contents of king crabs collected *via* trawls in Kiliuda Bay - August 1978 70

Table XXI. Stomach contents of king crabs collected *via* trawls in Kiliuda Bay - November 1978 71

Table XXII. Stomach contents of king crabs collected *via* trawls in Kiliuda Bay - March 1979. 72

Table XXIII. Stomach contents of king crabs collected *via* SCUBA in Near Island Basin - May 1978 74

Table XXIV. Stomach contents of king crabs collected *via* SCUBA in Near Island Basin - June 1978. 76

Table XXV. Stomach contents of king crabs collected *via* SCUBA in Near Island Basin - May 1979 78

Table XXVI. Stomach contents of king crabs collected *via* SCUBA near McLinn Island - May 1978 79

Table XXVII. Stomach contents of king crabs collected *via* SCUBA near McLinn Island - May 1979 81

Table XXVIII. Stomach contents of king crabs collected *via* SCUBA at Anton Larsen Bay (Site #1) - June 1978 82

Table XXIX. Stomach contents of king crabs collected *via* SCUBA at Anton Larsen Bay (Site #2) - June 1978 84

Table XXX. Stomach contents of king crabs collected *via* SCUBA in Anton Larsen Bay (Site #2) - May 1979. 85

Table XXXI. Stomach contents of king crabs collected *via* trawls on the Kodiak shelf - June-July 1978 87

Table XXXII. Station data and stomach contents of king crabs collected *via* trawls on the Kodiak shelf - June-July 1978. 88

LIST OF TABLES (Continued)

Table XXXIII. Stomach contents of king crabs collected *via* trawls on the Kodiak shelf - February 1979. 90

Table XXXIV. Station data and stomach contents of king crabs collected *via* trawls on the Kodiak shelf, February 1979 91

Table XXXV. Data employed in the Wilcoxon Rank Sum Test for consideration of difference between amount of food consumed between sexes of king crab. 92

Table XXXVI. Summary of the stomach contents of *Paralithodes camtschatica* for 809 crabs examined 94

Table XXXVII. Summary of stomach contents of *Paralithodes camtschatica* by size groups 95

Table XXXVIII. Kruskal-Wallis one-way analysis of variance for king crab food weight and crab size groups. 96

Table XXXIX. Kruskal-Wallis one-way analysis of variance for king crab stomach fullness and crab size groups 97

Table XL. Kruskal-Wallis one-way analysis of variance for king crab food weight and crab classes. 99

Table XLI. Kruskal-Wallis one-way analysis of variance for king crab food weight and sampling period 100

Table XLII. Kruskal-Wallis one-way analysis of variance for king crab food weight and sampling area 101

Table XLIII. Kruskal-Wallis one-way analysis of variance for king crab food weight and depth 103

Table XLIV. Numbers and locations of snow crabs examined for food contents 104

Table XLV. Numbers and locations of snow crabs examined for food contents 105

Table XLVI. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - April 1978. 106

Table XLVII. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - May 1978. 108

Table XLVIII. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - June 1978 109

LIST OF TABLES (Continued)

Table IL. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - July 1978. 111

Table L. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - August 1978. 113

Table LI. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - November 1978. 114

Table LII. Stomach contents of snow crabs collected *via* trawls in Izhut Bay - March 1979 116

Table LIII. Stomach contents of snow crabs collected *via* trawls in Kiliuda Bay - April 1978 117

Table LIV. Stomach contents of snow crabs collected *via* trawls in Kiliuda Bay - June 1978. 119

Table LV. Stomach contents of snow crabs collected *via* trawls in Kiliuda Bay - July 1978. 120

Table LVI. Stomach contents of snow crabs collected *via* trawls in Kiliuda Bay - August 1978. 122

Table LVII. Stomach contents of snow crabs collected *via* trawls in Kiliuda Bay - November 1978. 123

Table LVIII. Stomach contents of snow crabs collected *via* trawls in Kiliuda Bay - March 1979 124

Table LIX. Stomach contents of snow crabs collected *via* trawls on the Kodiak shelf - March 1978. 126

Table LX. Stomach contents of snow crabs collected *via* trawls on the Kodiak shelf - June-July 1978. 127

Table LXI. Station data and stomach contents of snow crabs collected on the Kodiak shelf - June-July 1978 128

Table LXII. Stomach contents of snow crabs collected *via* trawls on the Kodiak shelf - February 1979 130

Table LXIII. Station data and stomach contents of snow crab - Kodiak shelf 131

Table LXIV. Data employed in the Wilcoxon Rank Sum Test for consideration of difference between amount of food consumed between sexes of snow crabs 133

LIST OF TABLES (Continued)

Table LXV. Summary of the stomach contents of *Chionoecetes bairdi* for 1025 crabs examined. 134

Table LXVI. Summary of stomach contents of *Chionoecetes bairdi* by size groups 135

Table LXVII. Kruskal-Wallis one-way analysis of variance for snow crab food weight and crab size groups. 136

Table LXVIII. Mann-Whitney one-way analysis of variance for snow crab food weight and crab class. 137

Table LXIX. Kruskal-Wallis one-way analysis of variance for snow crab food weight and sampling period 139

Table LXX. Kruskal-Wallis one-way analysis of variance for snow crab food weight and sampling area 140

Table LXXI. Kruskal-Wallis one-way analysis of variance for snow crab food weight and depth 141

Table LXXII. Dominant stomach contents of pink shrimp from the Kodiak Island region, 1978-79 142

Table LXXIII. Stomach contents of the sun flower sea star from Izhut Bay, Afognak Island Region, 1978. 148

Table LXXIV. Stomach contents of selected fishes from the Kodiak Island region, 1978-79 152

Appendix A. Benthic trawl and SCUBA stations occupied in the Kodiak region, 1978-79. 201

Appendix B - Table I. Intestine contents of king crabs from the Kodiak Island region, 1978. 205

Appendix B - Table II. Stomach contents of snow crab $\leq$ 40 mm carapace width from the Kodiak Island Region, 1978-79 221

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

Until recently little was known about the biology of the invertebrates of the shallow, nearshore benthos of Kodiak Island. Since these invertebrates may be the ones most affected by petroleum operations in waters adjacent to Kodiak Island, baseline data on these species are essential before industrial activities begin there.

The specific objectives of this investigation were:

1. On a limited basis, assess distribution and relative abundance of epifaunal invertebrates, exclusive of king and snow crabs, in selected bays and inshore areas.
2. Using available data, assess the distribution and abundance of king crabs and snow crabs in selected bays and inshore areas, and selected offshore areas.
3. Using available data, assess spatial distribution of selected, infaunal invertebrate species.
4. Determine, where possible, the feeding habits of the principal inshore epifaunal invertebrate species exclusive on king crab (see 5 below); the food habits of the pink shrimp and the snow crab are to be especially examined.
5. Continue studies on the feeding habits of the king crab. The following listed objectives should eventually delineate (a) what the major geographic areas are that support (in terms of food) king crab of various sizes and life stages, and (b) which food item(s) or group(s) are most important to the enhancement of the size of a particular king crab stock.
    a. Examine, to the extent that collected material permits, the percent weight and/or volume composition of prey items of king crab of different sex, length and ecdysis stage by area (depth) and time of year.
    b. Examine the feeding intensity of king crab following the same parameters as in objective (a) above.
    c. Examine the relationship between catch number of king crab and their feeding intensity as determined by objective (b).

BEST DOCUMENT AVAILABLE

6. Develop food webs integrating invertebrate, fish and bird feeding data in collaboration with the Alaska Department of Fish and Game R.U. 552.

7. Compile seasonal reproductive data, and other biological data whenever possible, on dominant benthic epifaunal invertebrates.

The majority of these objectives have been met and are included in the present report.

Forty-six permanent benthic stations were established in two bays — 29 stations in Izhut Bay and 17 stations in Kiliuda Bay. These stations were sampled with a try net and/or a 400-mesh Eastern otter trawl on seven separate cruises: April, May, June, July, August, November 1978 and March 1979. Taxonomic analysis of the epifauna collected delineated nine phyla in each bay. The dominant invertebrate species and distinct biomass differences between the bays. Important species, in terms of biomass, in Izhut Bay were snow crabs (*Chionoecetes bairdi*) and sunflower sea stars (*Pycnopodia helianthoides*). Kiliuda Bay was dominated by king crabs (*Paralithodes camtschatica*), snow crabs, and pink shrimps (*Pandalus borealis*).

Offshore sampling was conducted in March 1978 adjacent to Portlock Bank and in June-July 1978 and February 1979 along the entire east side of the Kodiak Island continental shelf. The most important groups, in terms of biomass, collected during March 1978 sampling was echinoderms, specifically sea stars and sea urchins. King and snow crabs were the second-most important group from this area. Kodiak shelf sampling in June-July and February revealed king and snow crabs as the dominant species.

Stomachs of 809 king crabs collected *via* trawling and spring SCUBA activities contained a wide variety of prey. The most important prey, in terms of biomass, were molluscs, crustaceans, and fishes. Prey of crabs from Izhut Bay was dominated by fishes. Crabs from Kiliuda Bay mainly preyed upon molluscs, specifically clams. Food obtained from king crabs from the June-July 1978 and February 1979 Kodiak shelf sampling consisted mainly of clams and cockles, however, crustaceans and fishes were also important. King crabs collected during SCUBA sampling mainly contained clams and acorn barnacles.

Sampling *via* SCUBA made it possible to examine areas that are otherwise excluded by conventional sampling gear. SCUBA sampling resulted in extended information on molting, mating and feeding activities of king crabs in the shallow, coastal waters of Kodiak Island.

Additional feeding data was compiled on snow crabs, pink shrimps, sunflower sea stars, and 11 species of demersal fishes.

The 1025 large snow crabs (> 40 mm carapace width) mainly contained crustaceans (juvenile snow crabs and pink shrimps), fishes, and molluscs (clams). An additional 475 small snow crabs (≤ 40 mm) were examined; sediment, bivalve molluscs and polychaetes most frequently occurred.

Frequently occurring prey within pink shrimps were sediment, diatoms, and crustaceans.

Pelecypod and gastropod molluscs dominated the diet of sunflower sea stars.

Important prey among the 11 demersal fishes were snow crabs, pink shrimps, miscellaneous fishes and pelecypods.

Comprehension of basic food interrelationships is essential for assesment of the potential impact of oil on the crab-shrimp-dominated benthic systems of the waters adjacent to Kodiak. The importance of deposit-feeding clams in the diet of king and snow crabs and some demersal fishes in Kodiak waters has been demonstrated by preliminary feeding data collected there. It is suggested that an understanding of the relationship between oil, sediment, deposit-feeding clams, and crabs be developed in a further attempt to understand the possible impact of oil on the commercially important species of crabs and fishes in the Kodiak area.

Initial assessment of data suggests that a few unique, abundant and/or large invertebrate species (king crab, snow crab, several species of clams) are characteristic of the areas investigated and that these species may represent organisms that could be useful for monitoring purposes.

It is suggested that a complete understanding of the benthic systems of Kodiak waters can only be obtained when the infauna is also assessed in conjunction with the epifauna. Based on stomach analyses, infaunal species are important food items for king and snow crabs. However, the infaunal components of Izhut and Kiliuda Bay have not been quantitatively investigated to date, and a program designed to examine the infauna should be initiated in the near future.

II. INTRODUCTION

GENERAL NATURE AND SCOPE OF STUDY

The operations connected with oil exploration, production, and transportation in the northeast Gulf of Alaska (NEGOA) and waters adjacent to Kodiak Island present a wide spectrum of potential dangers to the marine environment (see Olson and Burgess, 1967 and Malins, 1977 for general discussion of marine pollution problems). Adverse effects on the marine environment of this area cannot be assessed, or even predicted, unless background data are recorded prior to industrial development.

Insufficient long-term information about an environment, and the basic biology and recruitment of species in that environment, can lead to erroneous interpretations of changes in types and density of species that might occur if the area becomes altered (see Nelson-Smith, 1973; Pearson, 1971, 1972, 1975; Rosenberg, 1973 for general discussions on benthic biological investigations in industrialized marine areas). Populations of marine species fluctuate over a time span of a few to 30 years, but such fluctuations are typically unexplainable because of the absence of long-term data (Lewis, 1970; and personal communication).

Benthic organisms (primarily the infauna but also sessile and slow-moving epifauna) are particularly useful as indicator species for a disturbed area because they tend to remain in place, typically react to long-range environmental changes, and by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects, and are believed to reflect the biological health of a marine area (see

Pearson, 1971, 1972, 1975 and Rosenberg, 1973 for discussion on long-term usage of benthic organisms for monitoring pollution; and Feder and Matheke, in press, for data and discussion on the infauna of NEGOA).

The presence of large numbers of epifaunal species of actual or potential commercial importance (crabs, shrimps, snails, finfishes) in NEGOA and on the shallow shelf adjacent to Kodiak Island further dictates the necessity of understanding benthic communities since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963 for a discussion of the interaction of commercial species and the benthos; also see appropriate discussion in Feder *et al.*, 1978; Feder and Jewett, 1980). Any drastic changes in density of the food benthos could affect the health and numbers of these commercially important species.

Experience in pollution-prone areas of England (Smith, 1968); Scotland (Pearson, 1972, 1975); and California (Straughan, 1971) suggests that at the completion of an initial study, selected stations should be examined regularly on a long-term basis to determine changes in species content, diversity, abundance and biomass. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration. Intensive investigations of the benthos of the Kodiak Continental Shelf are essential to understand the trophic interactions involved in this area and the changes that might take place once oil-related activities are initiated.

The benthic biological program in NEGOA (Feder, 1978) has emphasized development of an inventory of species as part of the examination by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of biological, physical and chemical components of shelf slated for oil exploration and drilling activity. In addition, a program designed to quantitatively assess assemblages (communities) of benthic species on the NEGOA shelf has expanded the understanding of distribution patterns of species there (Feder *et al.*, 1978; Feder and Matheke, in press). Investigations connected with distribution, abundance, community structure, and trophic relationships of benthic species in Cook Inlet, two Kodiak Island bays, and the S. E. Bering Sea have recently been completed (Feder *et al.*, 1978; Feder and Jewett, 1977; Feder and Jewett, 1980). However, detailed information on the temporal and spatial variability of the benthic fauna is sparse.

The project considered in this Final Report was designed to survey the benthic fauna including feeding interactions, on the Kodiak Island shelf in regions of potential oil and gas concentrations. Data were obtained seasonally on faunal composition and abundance to develop baselines to which future changes could be compared. Long-term studies on life histories and trophic interactions of important species should define aspects of communities and ecosystems potentially vulnerable to environmental damage, and should help to determine rates at which damaged environments can recover.

RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

Lack of an adequate data base elsewhere makes it difficult to predict the effects of oil-related activity on the subtidal benthos of the Kodiak shelf. However, OCSEAP — sponsored research activities on the shelf should ultimately enable us to point to certain species or areas that might bear closer scrutiny once industrial activity is initiated. It must be emphasized that a considerable time frame is needed to comprehend long-term fluctuations in density of marine benthic species; thus, it cannot be expected that short-term research programs will result in predictive capabilities. Assessment of the environment must be conducted on a continuing basis.

As indicated previously, infaunal organisms tend to remain in place and, consequently, have been useful as indicator species for disturbed areas. Thus, close examination of stations with substantial complements of infaunal species is warranted (see Feder and Mueller, 1975; Feder and Matheke, in press, and NODC data on file for examples of such stations). Changes in the environment at stations with relatively large numbers of species might be reflected by a decrease in diversity with increased dominance of few species (see Nelson-Smith, 1973 for further discussion of oil-related changes in diversity). The potential effects of loss of certain species (i.e. molluscs and polychaetes) to the trophic structure on the Kodiak shelf cannot be assessed at this time, but it is expected to have profound impact on commercially important benthic species (Jewett and Feder, 1976; Feder *et al.*, 1978; Feder and Jewett, 1977, 1978; Smith *et al.*, 1978).

Data indicating the effect of oil on subtidal benthic invertebrates are fragmentary (see Boesch *et al.*, 1974; Malins, 1977; and Nelson-Smith, 1973 for reviews; Baker, 1976 for a general review of marine ecology and oil pollution), and virtually no data are available for the Kodiak shelf. Snow crabs (*Chionoecetes bairdi*) are conspicuous members of the shallow shelf of the Gulf of Alaska, inclusive of the Kodiak region, and this species supports a commercial fishery of considerable importance. Laboratory experiments with this species have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil; obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this species (Karinen and Rice, 1974). Mecklenburg *et al.* (1976) examined the effects of Cook Inlet crude oil water soluble fractions on survival and molting of king crab (*Paralithodes camtschatica*) and coonstripe shrimp (*Pandalus hypsinotus*) larvae. Molting was permanently inhibited by exposing both larvae for 72 hours at a concentration of 0.8 to 0.9 ppm. Larvae that failed to molt had died in seven days, although the contaminated water had been replaced with clean water. Although high concentrations of oil killed the larvae in 96 hours, lower concentrations disrupted swimming and molting in the same period and also ultimately resulted in death. Little other direct data based on laboratory experiments are available for subtidal benthic species. Experimentation on toxic effects of oil on other common members of the subtidal benthos should be encouraged in future OCSEAP programs.

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974 for review). A diesel fuel spill resulted in oil becoming absorbed on sediment particles with resultant mortality of many deposit feeders on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. The most common members of the infauna of the Gulf of Alaska and the Bering Sea are deposit feeders; thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime with subsequent alteration of species composition.

As suggested above, upon completion of initial baseline studies in pollution prone areas, selected stations should be examined regularly on a long-term basis. Also, intensive examination of the biology (e.g., age, growth, condition, reproduction, recruitment, and feeding habits) of selected species should afford obvious clues of environmental alteration.

III. CURRENT STATE OF KNOWLEDGE

Few data on non-commercially important invertebrates of the nearshore benthos of the Gulf of Alaska were published until recent OCSEAP studies were initiated, e.g. Jewett and Feder (1976), Feder and Jewett (1977) and Feder and Hoberg (1980), although a summary of information prior to OCSEAP was available in the literature review of Rosenberg (1972). To date, Soviet workers have published most of the data from the western Gulf of Alaska (AEIDC, 1974); however, OCSEAP investigations in the northeast Gulf of Alaska (NEGOA) provide some useful data from adjacent areas (Jewett and Feder, 1976; Feder and Hoberg, 1980; Feder *et al.*, 1978). The Soviet benthic work was accomplished in the deeper waters of the Kodiak shelf, and was of a semi-quantitative nature with little data useful for predicting the effects of oil on the benthos.

The exploratory trawl program of the National Marine Fisheries Service is the most extensive investigation of commercially important species of the Kodiak shelf (Ronholt *et al.*, 1978; unpublished data; reports available from the National Marine Fisheries Service Laboratory, Kodiak). Some information on non-commercial invertebrate species is included in the data reports of the National Marine Fisheries Service, but the general nature of the taxonomy of species caught on their surveys makes their data difficult to interpret. However, the dominant groups of organisms likely to be encountered in the offshore waters of the Kodiak shelf are suggested by these studies. The International Pacific Halibut Commission surveys parts of the Kodiak shelf annually, but only records commercially important species of crabs and fishes; non-commercially important invertebrate and fish species are generally lumped together in the survey reports with little specific information available.

Additional, but unpublished data on the epifauna in the vicinity of Kodiak Island are available as a by-product of the Alaska Department of Fish and Game King Crab Indexing Surveys (inquiries concerning these reports may be directed to Alaska Department of Fish and Game, Box 686, Kodiak).

A compilation of data on renewable resources of the Kodiak shelf is included in the publication on Kodiak by AEIDC (1974).

A recent inshore survey of the Kodiak shelf examined the invertebrate benthos, and collected limited data on the food of the yellowfin sole (Feder and Jewett, 1977). This study investigated the distribution, abundance, aspects of reproduction, and feeding interactions of the benthos of two bays of Kodiak Island, Alitak and Ugak Bays. The food of the Pacific cod and two species of sculpins from the outer Kodiak shelf are presented in Jewett (1978) and Jewett and Powell (1979), respectively. Sufficient data were available from these studies and MacDonald and Peterson (1976) to develop a preliminary food web for the two bays and inshore waters around Kodiak Island (Feder and Jewett, 1977). The potential response of the inshore benthic system to oil-related activities in the two bays and inshore waters around Kodiak Island is discussed in Feder and Jewett (1977).

Commercial catch statistics of Kodiak crab stocks in past years showed classic exploitation patterns with a peak year catch occurring in the 1965-66 season. Since that time, annual harvest levels (quota) have been imposed. Recent data substantiate that king crab stocks are responding to the reduced fishing pressure resulting from this management decision, and populations are apparently in the rebuilding phase. The two most commercially utilized stocks are southern district stocks II and III which cover Kodiak Island's southern waters to the continental shelf edge (Guy Powell and Alaska Department of Fish and Game Reports, unpub.). Recent trawl studies conducted in two Kodiak Bays (Alitak and Ugak) show king crabs as the dominant species there (Feder and Jewett, 1977). Alitak Bay is also a major king crab breeding area (Gray and Powell, 1966; Kingsbury and James, 1971).

Based on OCSEAP feeding studies initiated in the northeast Gulf of Alaska (inclusive of Cook Inlet) and two bays on Kodiak Island (Feder *et al.*, 1978a; Feder and Jewett, 1977), it is apparent that benthic invertebrates play a major role in the food dynamics of commercial crabs and demersal fishes on the Kodiak shelf.

Although OCSEAP-sponsored research has initiated some inshore benthic studies in the Kodiak area, the coverage has been restricted geographically. Furthermore, little offshore benthic data is available to integrate with the inshore benthic work. Species found in bays, shallow inshore areas and deeper benthos of the Kodiak shelf are all highly mobile. and some of the more important species (e.g. king crabs, snow crabs, halibut) migrate between deep and shallow water during the course of a year. Data collected for these species only from inshore areas will not address their biological interactions in deeper shelf waters. Expansion of the data base from inshore to offshore waters is especially important to fully comprehend the biology of the commercially important king crab. The commercial pursuit of the latter species results in the most important invertebrate fishery in Alaska waters, and Kodiak king crab stocks support a substantial portion of the fishery.

IV. STUDY AREA

A large number of stations were occupied on the Kodiak Continental Shelf in conjunction with the Alaska Department of Fish and Game and National Marine Fisheries Service (Appendix A, Table 1). Inshore areas most extensively sampled by trawl included Izhut Bay, located on the southeast side of Afognak Island (Fig. 1), and Kiliuda Bay, located on the east side of Kodiak Island (Fig. 2). Additional inshore areas were sampled on Kodiak Island by SCUBA: Near Island Basin; McLinn Island, and Anton Larsen Bay (Fig. 3). Outer shelf stations were sampled by otter trawl and pipe dredge along the east side of the Kodiak Island Shelf (Figs. 4 and 5).

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Data on benthic epifauna, including feeding data on invertebrates and fishes, were collected during ten cruises in 1978-79. The NOAA Ship *Miller Freeman* was used primarily for offshore sampling, and the M/V *Yankee Clipper* and the R/V *Commando* were used primarily for inshore collecting.

Sampling from the *Miller Freeman* was conducted 21-24 March 1978, 19 June-9 July 1978, and 14-24 February 1979 using a commercial-size 400-mesh Eastern otter trawl (12.2 m horizontal opening). A pipe dredge was also used from the *Freeman* in June-July 1978 and February 1979 to obtain invertebrates to aid in the identification of invertebrate and fish stomach contents.

The *Yankee Clipper* sampled 10-22 April, 7-15 May, 7-22 June, 9-21 July, and 8-23 August 1978. The *Commando* also sampled 7-15 May, 7-22 June, 9-21 July, and 8-23 August 1978, in addition to 4-17 November 1978 and 1-20 March 1979. A try net (6.1 m horizontal opening) was used from the *Clipper*, and a try net and Eastern otter trawl were used from the *Commando*.

Exploratory diving for crabs, *via* SCUBA, was conducted near the city of Kodiak in May, June and October 1978 and May 1979. SCUBA-caught

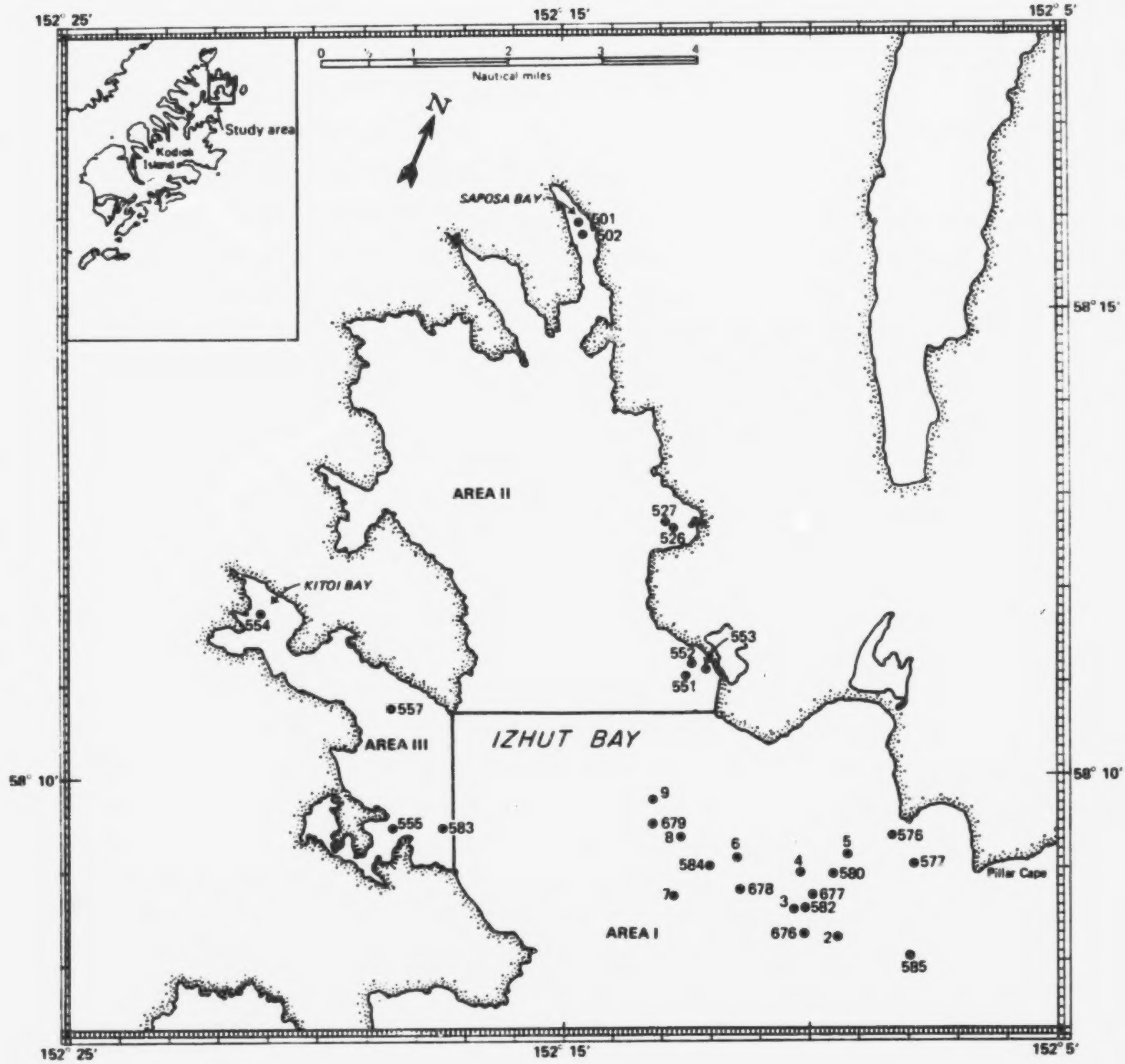

152° 25'
152° 15'
152° 5'
58° 15'
58° 10'
0
½
1
2
3
4
Nautical miles
N
Study area
Kodiak Island
SAPOSA BAY
501
502
AREA II
527
526
KITOI BAY
554
553
552
551
557
AREA III
IZHUT BAY
9
679
8
6
5
576
584
4
580
577
Pillar Cape
555
583
7
678
677
3
582
AREA I
676
2
585

Figure 1. Benthic trawl stations occupied in Izhut Bay, Afognak Island, 1978-79. The bay is divided into three areas which are referred to in the text.

BEST DOCUMENT AVAILABLE

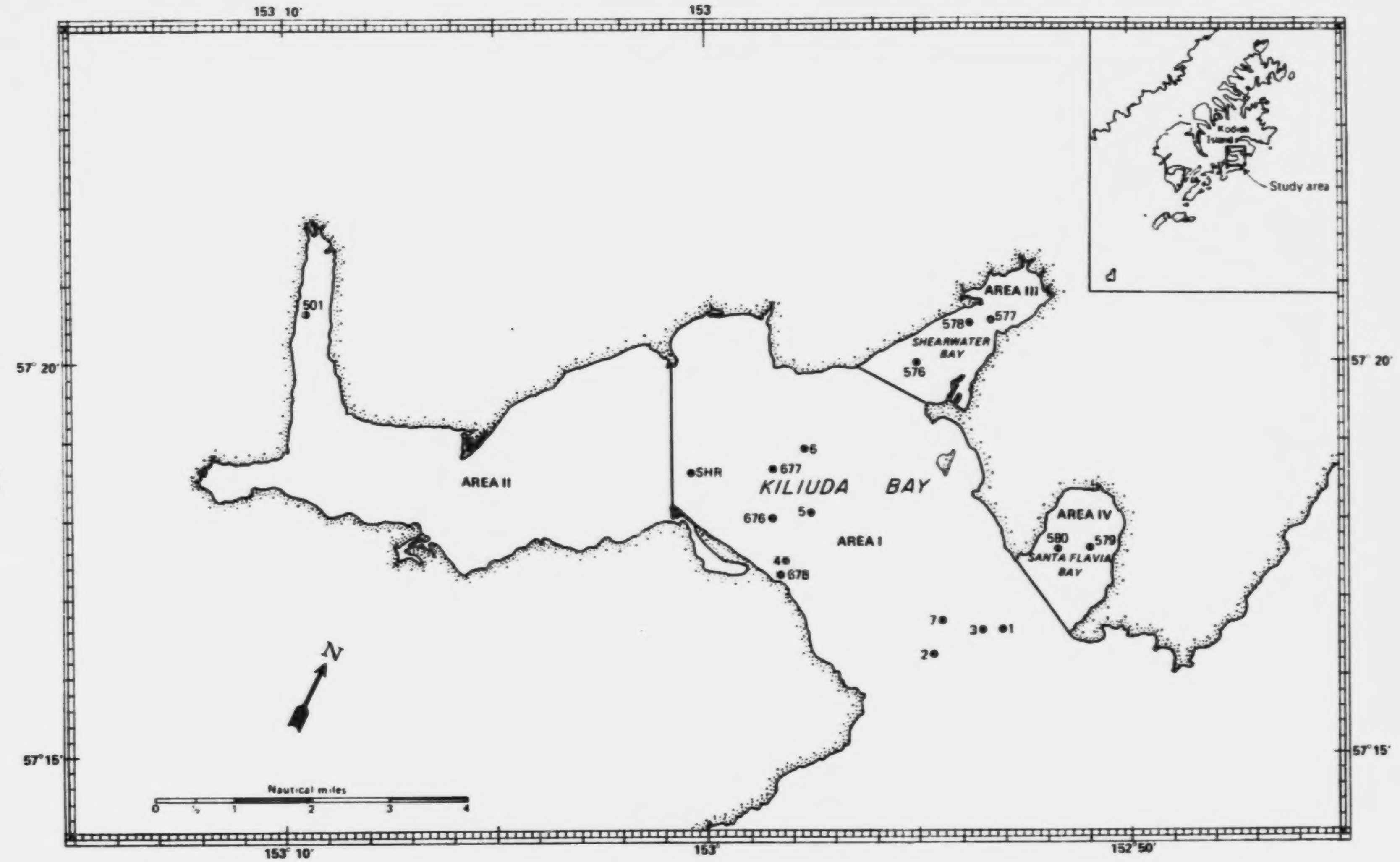

153 10'
153
57° 20'
57° 15'
153° 10'
153°
152°50'
AREA II
AREA I
AREA III
AREA IV
KILIUDA BAY
SHEARWATER BAY
SANTA FLAVIA BAY
501
SHR
677
6
676
5
4
678
7
3
1
2
578
577
576
580
579
N
Nautical miles
0
½
1
2
3
4
Kodiak Island
Study area

Figure 2. Benthic trawl stations occupied in Kiliuda Bay, Kodiak Island, 1978-79. The bay is divided into four areas which are referred to in the text.

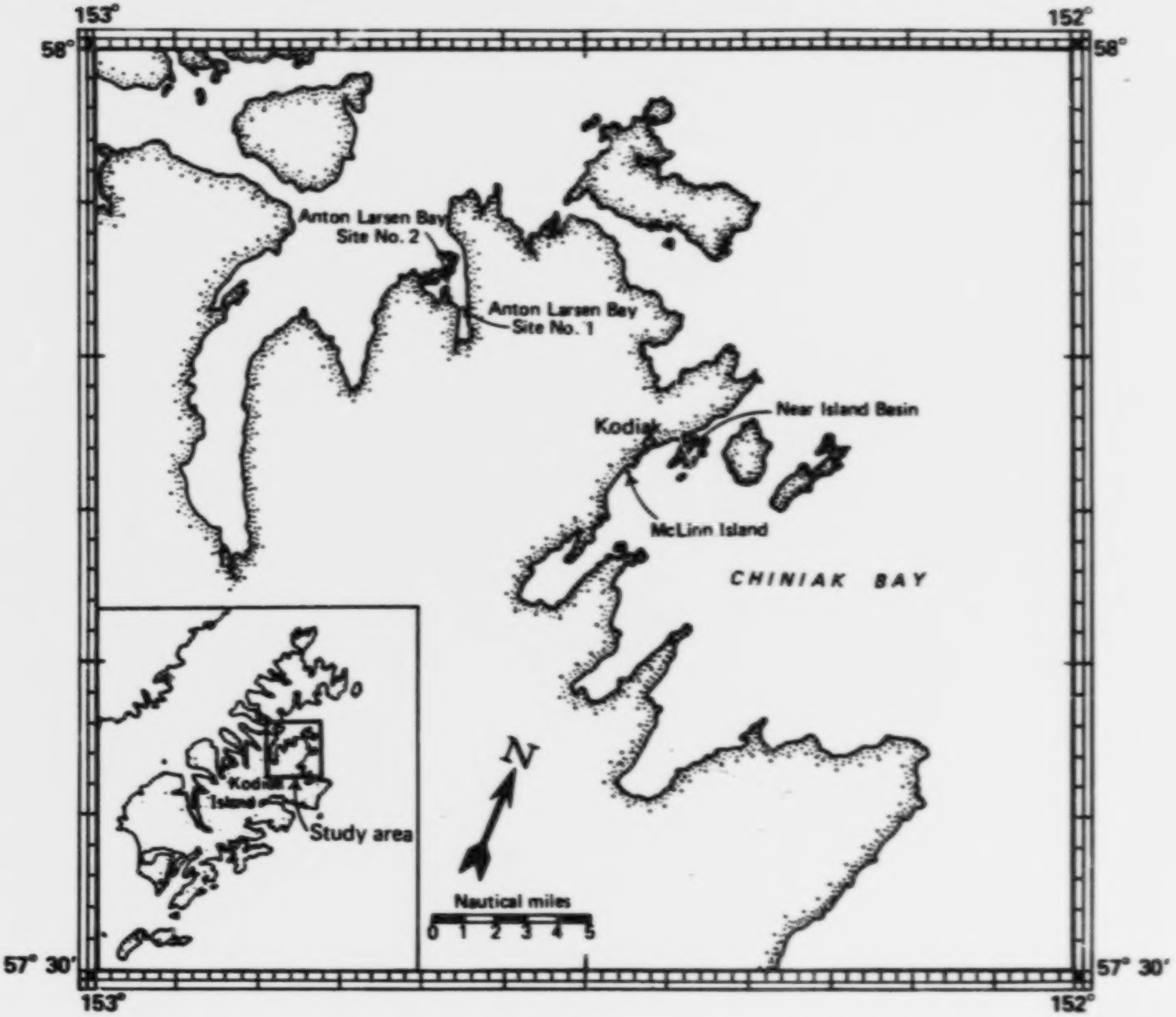

153°
152°
58°
58°
Anton Larsen Bay Site No. 2
Anton Larsen Bay Site No. 1
Kodiak
Near Island Basin
McLinn Island
CHINIAK BAY
Kodiak Island
Study area
N
Nautical miles
0 1 2 3 4 5
57° 30'
57° 30'
153°
152°

Figure 3. Locations where king crabs were collected *via* SCUBA for stomach analysis, 1978-79.

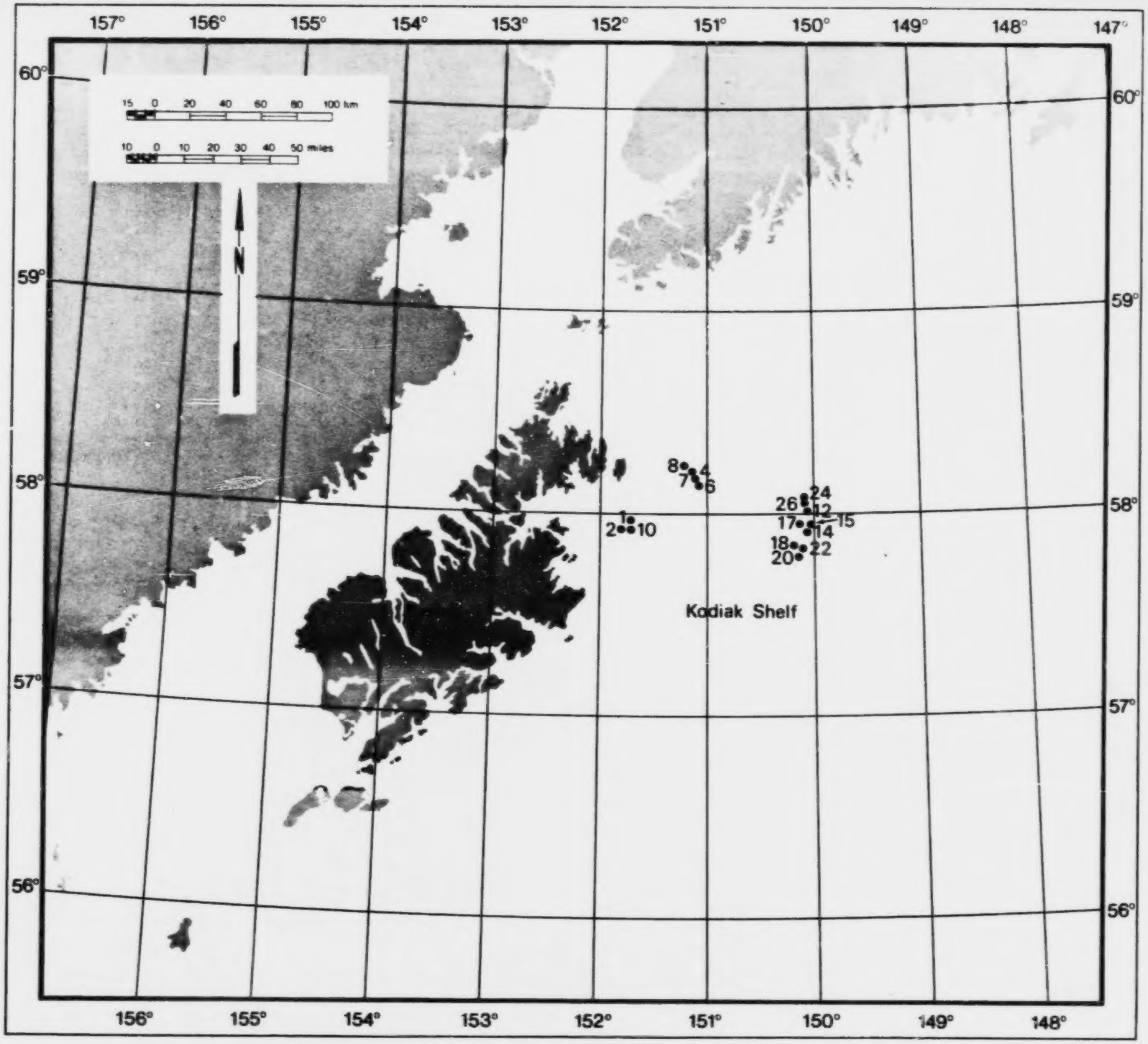

157°
156°
155°
154°
153°
152°
151°
150°
149°
148°
147°
60°
59°
58°
57°
56°
15 0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
N
8
4
7
6
1
2
10
26
24
12
15
17
14
18
22
20
Kodiak Shelf

Figure 4. Benthic trawl stations occupied in March, 1978.

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

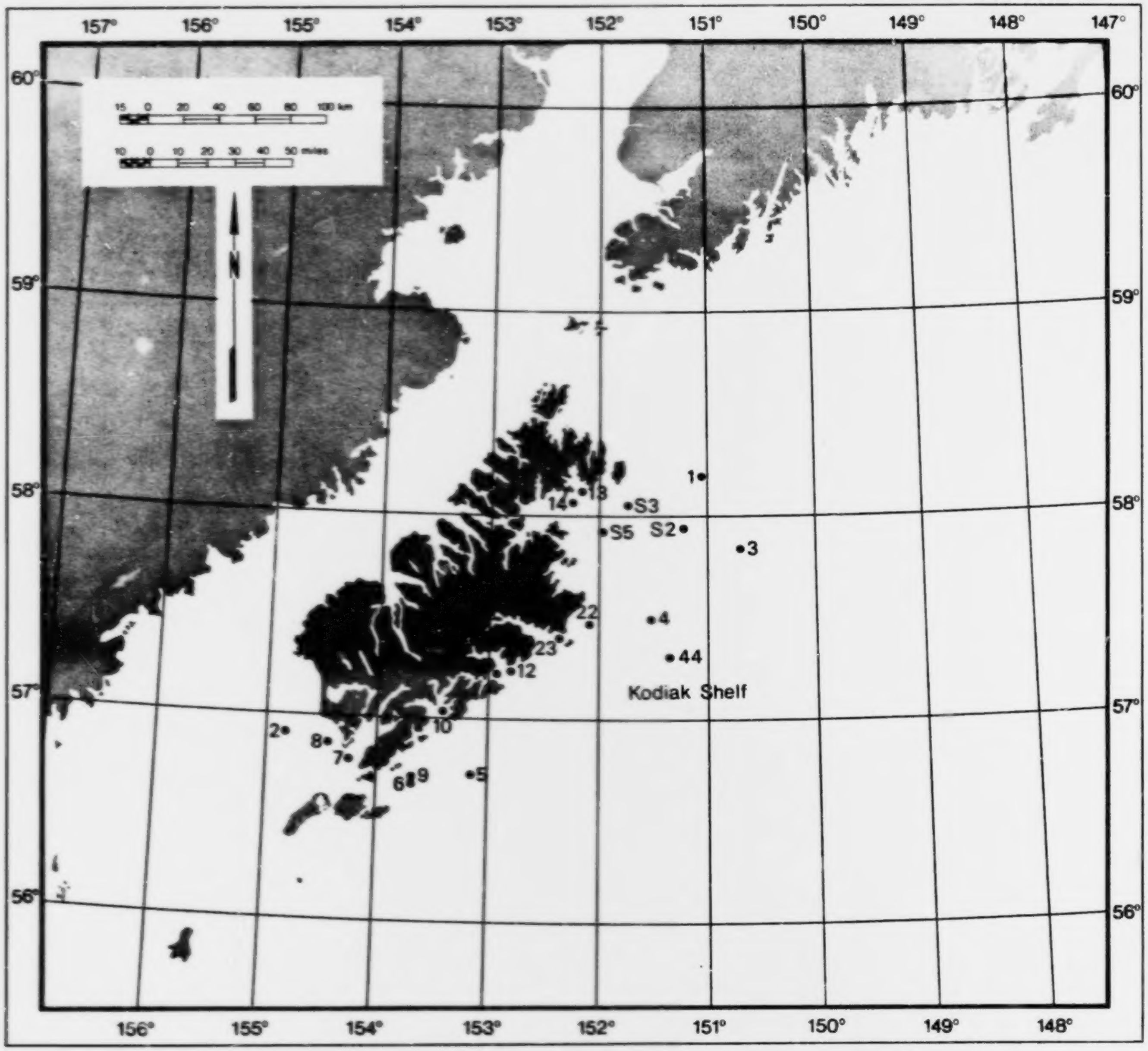

157°
156°
155°
154°
153°
152°
151°
150°
149°
148°
147°
60°
59°
58°
57°
56°
15 0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
N
1
13
14
S3
S5
S2
3
22
4
23
44
12
Kodiak Shelf
10
2
8
7
6
9
5

Figure 5. Benthic stations occupied in June-July, 1978 and February, 1979.

king crabs, obtained for stomach analysis, were caught at Near Island Basin, Anton Larsen Bay and near McLinn Island.

Sediment sweeps were obtained *via* SCUBA in October 1978 and May 1979 in Near Island Basin. The sweeps were obtained with a fine-mesh nylon net supported on a 30 x 90 cm steel frame. The net was swept across the sediment surface penetrating approximately 7 cm. Sweeps were made to obtain juvenile snow crab and potential crab prey.

Invertebrates from the trawls were sorted on shipboard, given tentative identifications, counted and weighed. Aliquot samples of individual taxa were labeled and preserved for final identification at the University of Alaska, Fairbanks. Invertebrates from the pipe dredge were sorted, identified, and counted at the University of Alaska. Noncommercial invertebrates from some Izhut and Kiliuda Bay stations in June and August were inadvertently not recorded.

Biomass per unit area (g/m^2) is included for all trawl data and is calculated as follows:

$$\text{Biomass} = \sum_{i=1}^{k} [\text{weight}/(\text{distance fished} \times \text{trawl width})]$$

Analysis of food habits of a variety of predators taken by trawl and SCUBA was conducted in the laboratory at the University of Alaska. A summary of the number of stomachs examined by sampling area and collection period is included in Tables I and II.

On shipboard, king crabs selected for stomach analysis were measured (length in millimeters) and weighed (wet weight in grams). Carapace length is defined as the distance from the posterior margin of the right orbital indentation to the mid-point of the posterior marginal indentation. Crabs were categorized as belonging to one of eight classes (adapted after Powell *et al.*, 1974): (1) juvenile newshell females less than 120 mm — individuals that molted during the last molting period; (2) adult newshell females greater than 94 mm; (3) newshell males less than 100 mm; (4) oldshell males less than 100 mm — individuals that failed to molt

TABLE I

THE NUMBER OF STOMACHS FROM EACH PREDATOR EXAMINED BY SAMPLING AREA AND COLLECTION PERIOD. ALL PREDATORS WERE TAKEN BY TRAWL.

Predators	Izhut Bay							Kiliuda Bay						Kodiak Shelf			TOTALS
	4-78	5-78	6-78	7-78	8-78	11-78	3-79	4-78	6-78	7-78	8-78	11-78	3-79	3-78	6-78	2-79	
	STOMACHS EXAMINED																
Paralithodes camtschatica (red king crab)	-	-	22	18	-	-	-	47	77	69	43	55	38	-	196	22	587
Chionoecetes bairdi (snow crab)	31	117	159	121	31	62	96	64	117	51	35	50	51	88	167	211	1451
Pandalus borealis (pink shrimp)	-	100	100	100	100	-	100	-	100	100	100	100	100	-	200	100	1300
Pycnopodia helianthoides (sunflower sea star)	-	105	44	-	14	36	-	-	-	-	-	-	-	-	-	-	199
Gadus macrocephalus (Pacific cod)	-	18	-	-	-	-	-	-	-	-	20	-	-	-	190	55	283
Theragra chalcogramma (walleye pollock)	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	20
Myoxocephalus spp. (sculpins)	-	19	-	-	-	-	-	-	-	-	-	-	-	-	72	12	103
Hemilepidotus jordani (yellow Irish lord)	-	-	-	-	-	-	-	-	-	-	-	-	-	39	189	90	318
Lepidopsetta bilineata (rock sole)	-	23	-	-	-	-	-	-	-	-	-	-	-	-	94	70	187
Hippoglossoides elassodon (flathead sole)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	156	90	246
Atheresthes stomias (arrowtooth flounder)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	18
Isopsetta isolepis (butter sole)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	20
Limanda aspera (yellowfin sole)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	50
Pleuogrammus monopterigius (Atka mackerel)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	20
Anaplopoma fimbria (sablefish)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	31

TABLE II

THE NUMBER OF CRAB STOMACHS EXAMINED BY SAMPLING AREA AND COLLECTION PERIOD. ALL CRABS WERE TAKEN BY SCUBA.

Predators	Near Island Basin				McLinn Island		Anton Larsen Bay		
	5-78	6-78	10-78	5-79	5-78	5-79	6-78	5-79	
	STOMACHS EXAMINED								TOTALS
Paralithodes camtschatica (red king crab)	35	32	-	21	49	16	52	17	222
Chionoecetes bairdi (snow crab)	-	-	49	-	-	-	-	-	49

during the last molting period, often referred to as skipmolts; (5) very oldshell males less than 100 mm — individuals that failed to molt during the last two or more molting periods, often referred to as double skipmolts; (6) newshell males greater than 100 mm; (7) oldshell males greater than 100 mm; and (8) very oldshell males greater than 100 mm. Stomachs[1] and intestines were removed and placed in plastic "Whirlpak" bags and fixed in 10% buffered formalin for final identification at the University of Alaska, Fairbanks.

In the laboratory, stomach contents were removed and sorted by taxon. Each taxon was blotted dry, weighed to the nearest 0.001 g, and measured volumetrically by water displacement to the nearest 0.01 ml. Taxon weighing was accomplished by weighing a vial with a known quantity of water and then weighing the vial and water plus the taxon. The difference in the two weights equal the taxon weight.

King crab stomach fullness was calculated using a method adapted from Cunningham (1969) for southeast Bering Sea king crabs. He delineated a curvilinear relationship between king crab length and the theoretical maximum stomach volume. To do this, he measured the maximum stomach volume of 216 crabs which ranged from 80-180 mm carapace length. The regression formula was $Y = 34.25 - 0.72x + 0.0047x^2$, and the correlation coefficient was 0.899. Since king crabs examined in our study were similar in size to those examined by Cunningham, we used his regression formula with our crabs to calculate the theoretical maximum volumes. The percent of fullness was derived by dividing the observed volume by the theoretical maximum volume. The prey in the intestines of king crabs were recorded by frequency of occurrence.

Three statistical procedures were mainly used in analyzing the food of crabs. The first procedure, the Wilcoxon Signed Ranks Test (Zar, 1974), is a nonparametric test designed to test the difference between paired observations. This test was used in determining feeding differences between sexes. The second procedure, the Kruskal-Wallis Test (Zar, 1974), is also a non-parametric test used to test the hypothesis that all treatment effects are the same versus the hypothesis that not all treatment effects are equal. This test was used in determining feeding differences between sampling areas, periods, depths and crab classes and sizes using rank sum values of food weights. A third procedure was employed to make multiple comparisons using the rank sums (Dunn, 1964).

---

[1] In this study, references to crab stomachs includes that portion extending from the terminal portion of the esophagus to the beginning of the intestine.

Snow crabs selected for stomach analysis were examined by two methods: (1) those with carapace widths greater than 40 mm were examined gravimetrically and volumetrically, similar to king crab stomachs; and (2) those with carapace widths 40 mm or less were examined by the frequency of occurrence method. Carapace width is defined as the straightline distance across the widest part of the carapace, excluding spines, at right angles to a line drawn from the rostrum to the medial posterior margin of the carapace. Stomachs of crabs > 40 mm were removed onboard ship and fixed in 10% buffered formalin for final identification at the University of Alaska. Snow crabs ≤ 40 mm were preserved in 10% buffered formalin and stomachs were removed and examined in the laboratory in Fairbanks. Snow crabs were categorized as belonging to one of two exoskeleton classes (Donaldson, 1977): (1) newshell — hard exoskeleton with the dorsal side of the carapace brownish-red, no apparent or limited scratching in ventral side, epifauna limited or lacking, and dactyli, pterygostomial and branchial spines sharp; (2) oldshell — an apparent skipmolt with carapace hard and brownish, thoracic sternum and ventral side of the legs have numerous scratches and abrasions, epifauna may be present, and dactyli, pterygostomial and branchial spines worn. Recently molted and very oldshell crabs were rarely found.

Statistical procedures used by snow crab were mainly those used by king crabs.

Since the weight of crab stomach contents was not normally distributed, but skewed, the median weight value was used, as opposed to the mean, as the measure of central tendency. This median value was used in all statistical analyses on crabs.

Fish and sea star stomachs were examined in the field when possible, and contents were recorded as frequency of occurrence.

Pink shrimp were preserved in the field and stomachs were examined in the laboratory by the frequency of occurrence method.

VI. RESULTS

TRAWL DATA: DISTRIBUTION-BIOMASS

Izhut Bay (Tables III-VIII; Appendix A; Figure 1)

April 1978

Eight stations were successfully trawled with a try net in Izhut Bay, April 1978. All station depths were less than 36 m. The mean epifaunal invertebrate biomass was 1.56 g/m^2, and the dominant phyla, in terms of percent biomass, were Porifera (21.9%) and Echinodermata (61.7%). Sponges were not identified to species. The leading echinoderm species was the sea star, *Pycnopodia helianthoides* (60.7%). The only commercially-important invertebrate was the snow crab, *Chionoecetes bairdi* which comprised 3.7% of the invertebrate biomass. The majority of snow crabs came from Kitoi Bay, Area III, station 554.

May 1978

A total of 14 stations were occupied in Izhut Bay in May; 12 with a try net and two with an otter trawl. The mean epifaunal invertebrate biomass for all stations was 1.83 g/m^2. Leading phyla were Arthropoda (Crustacea) (44% of the biomass) and Echinodermata (50.8%). Arthropods consisted primarily of the pink shrimp, *Pandalus borealis* (22.5%), *Chionoecetes bairdi* (12.7%), the king crab, *Paralithodes camtschatica* (3.9%), and the dungeness crab, *Cancer magister* (3.7%). The largest catch of *P. borealis* came from Area III at station 557; 33.7 kg or 3.45 g/m^2. The largest snow crab catch was 26.5 kg in Area I at station 3. Dominant echinoderms were the sea stars, *Pycnopodia helianthoides* (37.9%) and *Stylasterias forreri* (11.4%).

June 1978

Benthic trawling in Izhut Bay in June was successfully accomplished at 14 stations, 11 try net stations and three otter trawl stations. Use

TABLE III

TRAWL STATIONS OCCUPIED IN IZHUT AND KILIUDA BAY, 1978-79, AND STATIONS WHERE LARGE NUMBERS OF KING CRABS, SNOW CRABS AND/OR PINK SHRIMP WERE COLLECTED

T = Try Net Stations, 0 = Otter Trawl Stations

Izhut Bay Stations	4-78	5-78	6-78	7-78	8-78	11-78	3-79
2	-	0	-	-	-	0	-
3	-	0^{*}	0	0	-	0	-
4	-	-	-	0	-	-	-
5	-	-	-	-	0	-	-
6	-	-	-	-	0^{*}	-	-
7	-	-	0^{+*}	-	-	0^{*}	-
8	-	-	0^{+*}	0^{*}	0^{*}	0	-
9	-	-	-	0^{+*}	-	-	-
501	T	T	T	-	-	-	-
502	-	T	T	T	-	-	-
526	-	T	T	$T^{\#}$	-	-	-
527	T	T	-	$T^{\#}$	T	T	-
551	T	-	-	T	T	T	T
552	T	T	T	T	T	T	T
553	T	T	T	T	T	T	-
554	T^{*}	-	T	T	T	T	T
555	-	T	-	T	T	T	T
557	-	$T^{\#}$	-	$T^{\#}$	$T^{\#}$	T	T
576	-	T	T	T	T	T	T
577	T	T	T	T	T	T	-
580	T	-	T	T	T	T	T
582	-	T	T	-	T	-	T
583	-	T	T	T	T	T	T
584	-	-	-	T	-	-	-
585	-	-	-	T	-	-	-
676	-	-	-	-	-	-	0
677	-	-	-	-	-	-	0
678	-	-	-	-	-	-	0
679	-	-	-	-	-	-	$0^{*\#}$

Kiliuda Bay Stations	4-78	6-78	7-78	8-78	11-78	3-79
1	-	-	0^{+}	-	-	-
2	-	-	-	0^{+*}	-	-
3	-	0^{+}	-	-	-	-
4	-	0^{+}	0^{+}	0	-	-
5	-	0^{*}	-	0^{+}	$0^{*\#}$	-
6	-	-	0^{*}	-	-	-
7	-	-	-	-	0^{+*}	-
501	-	-	T	T	T	T^{*}
576	T^{+}	T	T	T	T	T
577	T	-	T	T	T	T
578	T^{+}	T	T	-	-	-
579	T^{+}	T	T^{+*}	T^{*}	T	T^{+}
580	T^{+}	T	T^{+*}	T	T	T
588	T	T	T	$T^{\#}$	$T^{+\#}$	-
676	-	-	-	-	-	$0^{\#}$
677	-	-	-	-	-	0
678	-	-	-	-	-	0

$^{+}$Important king crab stations

*Important snow crab stations

$^{\#}$Important pink shrimp stations

TABLE IV

SUMMARY OF TRAWL ACTIVITIES FROM IZHUT AND KILIUDA BAYS, 1978

		Izhut Bay				Kiliuda Bay			
Date	Gear	Successful Stations	Distance Fished, km	Invertebrate Weight, kg	Mean Biomass g/m^2	Successful Stations	Distance Fished, km	Invertebrate Weight, kg	Mean Biomass g/m^2
April 10-22/78	Try-Net	8	6.33	60.611	1.56	6	9.14	113.669	2.04
May 7-15/78	Try-Net	12	12.00	95.837	-	-	-	-	-
	Otter Trawl	2	3.70	121.420	-	-	-	-	-
	TOTALS	14	15.70	217.257	1.83				
June 7-22/78	Try-Net	11	8.80	77.598	-	5	7.20	59.326	-
	Otter Trawl	3	4.80	719.886	-	3	2.40	209.850	-
	TOTALS	14	13.60	797.484	7.10	8	9.60	269.176	3.68
July 9-21/78	Try-Net	15	15.50	129.996	-	7	7.11	72.440	-
	Otter Trawl	4	6.40	342.725	-	3	4.80	154.970	-
	TOTALS	19	21.90	472.721	2.74	10	11.91	227.410	2.23
August 8-23/78	Try-Net	12	14.36	372.343	-	6	5.80	281.069	-
	Otter Trawl	3	5.30	147.800	-	3	4.80	159.755	-
	TOTALS	15	19.66	520.143	3.41	9	10.60	440.824	4.69
November 4-17/78	Try-Net	11	10.40	51.154	-	6	5.60	163.959	-
	Otter Trawl	4	7.40	280.774	-	2	1.60	102.000	-
	TOTALS	15	17.80	331.928	2.16	8	7.20	265.959	4.95
March 1-20/79	Try-Net	9	5.60	30.970	-	5	3.00	97.669	-
	Otter Trawl	4	4.40	806.003	-	3	5.55	85.983	-
	TOTALS	13	10.00	836.973	9.53	8	8.55	183.652	2.13

TABLE V

PERCENT BIOMASS COMPOSITION OF THE INVERTEBRATE PHYLA OF IZHUT AND KILIUDA BAYS, 1978-79

	Izhut Bay						
PHYLUM	4-78	5-78	6-78	7-78	8-78	11-78	3-79
Porifera	21.93	0	0	0.30	0	<0.01	0.07
Cnidaria	7.49	2.26	0.29	2.80	0.05	2.17	1.02
Annelida	0.06	<0.01	0.08	0.09	0	<0.01	<0.01
Mollusca	2.09	2.89	0.09	4.58	2.10	0.16	0.22
Arthropoda	5.76	43.99	83.45	58.71	64.70	56.92	90.47
Ectoprocta	<0.01	0	0	0.04	0	0.01	<0.01
Brachiopoda	<0.01	0	0	0.01	<0.01	0	0
Echinodermata	61.72	50.84	15.58	33.33	32.98	40.28	8.19
Urochordata	0.95	0.02	0.50	0.14	0.15	0.45	<0.01
	Kiliuda Bay						
Porifera	0.09	N	0	0.01	0	0.02	<0.01
Cnidaria	0	O	0	13.93	0.04	0.91	24.51
Annelida	0.07		0	<0.01	0	0.02	0.03
Mollusca	6.90	S	0	3.58	2.35	2.76	0.89
Arthropoda	90.42	A	100.00	81.90	96.97	96.12	67.68
Ectoprocta	<0.01	M	0	0.07	0	0	<0.01
Brachiopoda	0	P	0	0	0	0	0
Echinodermata	2.42	L	0	0.67	0.63	0.17	6.87
Urochordata	0.10	E	0	0.05	0	0	0

TABLE VI

PERCENT BIOMASS COMPOSITION OF THE INVERTEBRATE FAMILIES OF IZHUT AND KILIUDA BAYS, 1978-79

	Izhut Bay						
FAMILY	4-78	5-78	6-78	7-78	8-78	11-78	3-79
Porifera (unid. family)	21.93	0	0	0	0	<1	0
Actiniidae	7.49	<1	0	0	0	<1	0
Metridiidae	0	1.99	<1	2.71	<1	<1	1.02
Pectiniidae	0	2.55	<1	1.03	<1	0	<1
Cymatiidae	0	<1	<1	<1	1.60	<1	<1
Dorididae	1.78	0	0	0	0	0	<1
Octopodidae	0	0	0	1.98	0	0	0
Pandalidae	<1	22.56	<1	14.83	44.84	<1	49.54
Paguridae	<1	<1	<1	1.26	<1	<1	<1
Lithodidae	0	3.93	3.30	5.44	<1	<1	<1
Majidae	4.59	13.12	78.85	30.12	14.98	44.80	39.86
Cancridae	<1	3.67	<1	6.62	3.67	10.68	<1
Asteridae	61.36	49.94	14.93	29.93	31.90	40.18	7.86
Ophiuridae	0	<1	<1	1.66	<1	0	0
Stichopodidae	0	0	<1	1.11	0	0	0
	Kiliuda Bay						
Cyaneidae	0	N	0	1.81	0	0	0
Metridiidae	0	O	0	12.11	<1	0	24.50
Cymatidae	5.43		0	2.67	1.69	1.25	<1
Pandalidae	11.12	S	0	3.68	69.26	59.46	2.22
Crangonidae	2.89	A	0	<1	<1	<1	<1
Lithodidae	72.89	M	72.95	48.16	11.35	24.42	52.43
Majidae	1.70	P	26.38	23.58	13.43	7.96	8.82
Cancridae	0	L	<1	4.81	2.05	3.51	3.30
Stichopodidae	2.11	E	0	<1	<1	0	<1

TABLE VII

PERCENT BIOMASS COMPOSITION OF THE INVERTEBRATES OF IZHUT AND KILIUDA BAYS, 1978-79

	Izhut Bay						
SPECIES	4-78	5-78	6-78	7-78	8-78	11-78	3-79
Porifera (unid. species)	21.93	0	0	0	0	<1	<1
Actiniidae (unid. species)	7.49	<1	0	0	0	0	0
Metridum senile	0	1.99	<1	2.71	<1	<1	1.03
Pecten caurinus	0	2.46	0	1.03	0	0	<1
Fusitriton oregonensis	0	<1	<1	<1	1.60	<1	<1
Dorididae (unid. species)	1.78	0	0	0	0	0	<1
Octopus sp.	0	0	0	1.98	0	0	0
Pandalus borealis	0	22.52	<1	12.28	44.82	<1	41.21
Pandalus hypsinotus	<1	<1	<1	1.08	<1	<1	8.33
Paralithodes camtschatica	0	3.93	3.30	5.44	<1	<1	<1
Chionoecetes bairdi	3.75	12.66	78.84	29.98	13.93	44.74	39.86
Cancer magister	0	3.66	<1	6.62	3.66	10.68	<1
Orthasterias koehleri	0	0	0	2.28	0	<1	<1
Evasterias troschelii	<1	<1	<1	<1	5.19	<1	0
Stylasterias forreri	0	11.40	0	0	0	0	0
Pycnopodia helianthoides	60.68	37.92	14.88	26.83	26.72	38.83	7.81
Ophiura sarsi	0	<1	<1	1.66	<1	0	0
Parastichopus californicus	0	0	0	1.11	0	0	0
	Kiliuda Bay						
Cyanea capillata	0	N	0	1.81	0	0	0
Metridium senile	0	O	0	12.11	<1	0	24.50
Fusitriton oregonensis	5.43		0	2.67	1.69	1.25	<1
Pandalus borealis	7.51	S	0	2.77	69.26	58.13	2.02
Pandalus goniurus	2.39	A	0	0	0	<1	<1
Pandalus hypsinotus	1.17	M	0	<1	0	<1	<1
Crangon dalli	2.27	P	0	<1	<1	<1	<1
Paralithodes camtschatica	72.89	L	72.95	48.16	11.35	24.42	52.44
Chionoecetes bairdi	<1	E	26.38	23.28	13.38	7.80	8.70
Cancer magister	0		<1	4.80	2.05	3.51	3.31
Dermasterias imbricata	0		0	0	0	0	2.29
Strongylocentrotus purpuratus	0		0	0	0	0	2.23
Parastichopus californicus	2.11		0	<1	<1	0	<1

BEST DOCUMENT AVAILABLE

TABLE VIII

INVERTEBRATES TAKEN BY TRAWL IN IZHUT BAY, 1978-79

X = Taxon Collected

Taxon	Common Name	Sampling Periods						
		4-78	5-78	6-78	7-78	8-78	11-78	3-79
Porifera	sponge	X					X	
Halichondria panicea	sponge				X			
Suberites spp.	sponge				X			X
Hydrozoa	hydroid				X		X	X
Scyphozoa	jellyfish					X		
Anthozoa	sea anemone, sea pen				X		X	
Ptilosarcus gurneyi	sea pen	X						
Actiniidae	sea anemone	X	X					
Tealia crassicornis	sea anemone						X	
Metridium senile	sea anemone	X	X			X	X	X
Ctenophora	comb jelly					X		
Polycladia	flat worm				X			
Polychaeta	segmented worm	X						
Arctonoe fragilis	segmented worm	X						
Arctonoe vittata	segmented worm				X			
Eunoe depressa	segmented worm				X			X
Eunoe clarki	segmented worm							X
Harmothoe imbricata	segmented worm		X					
Cheilonereis cyclurus	segmented worm				X		X	X
Nereis sp.	segmented worm			X	X			
Platynereis bicanaliculata	segmented worm	X						
Nephtys puncata	segmented worm				X			
Flabelligera affinis	segmented worm	X						
Idanthyrus armatus	segmented worm				X			
Ammotrypane aulogaster	segmented worm							X
Crucigera zygophora	segmented tube worm				X			
Aplacophora	solengaster	X						
Mopalia swanii	chiton	X						
Yoldia amydalea	almond *Yoldia*			X	X			
Mytilus edulis	mussel			X				
Chlamys rubida	Hinds' scallop		X	X	X	X		X
Pecten caurinus	weathervane scallop		X		X			X
Glycymeris subobsoleta	west coast bittersweet				X	X	X	
Pododesmus macrochisma	sea jingle	X	X					
Modiolus modiolus	northern horse mussel						X	
Astarte spp.	clam			X				
Astarte rollandi	clam				X			
Cyclocardia crebricostata	cockle			X		X		
Clinocardium ciliatum	Iceland cockle	X	X		X			
Clinocardium fucanum	fucan cockle		X		X		X	
Serripes groenlandicus	Greenland cockle	X	X	X	X			
Serripes laperousii	cockle				X			
Humilaria kennerleyi	Kennerley's Venus		X	X				
Compsomyax subdiaphana	milky Pacific Venus				X			
Tellina nuculoides	Salmon Tellin	X						
Macoma spp.	clam			X		X	X	
Macoma lipara	clam		X					
Macoma brota	Brota *Macoma*				X			
Macoma obliqua	incongruous Macoma				X			
Siliqua alta	Dall's razor clam					X		
Hiatella arctica	Arctic Nestler clam	X			X			
Mya truncata	soft shell clam		X				X	
Puncturella galeata	helmet Puncturella	X						
Cryptobranchia alba	limpet	X						
Collisella spp.	limpet		X		X			
Collisella ochracea	limpet		X			X		
Margarites pupillus	puppet Margarite	X	X		X	X		
Crepidula spp.	slipper shell				X			
Crepidula nummaria	slipper shell	X			X			
Trichotropis cancellata	cancellate hairy-shell	X						
Polinices pallida	moon-shell					X		X

BEST DOCUMENT AVAILABLE

TABLE VIII

CONTINUED

Taxon	Common Name	Sampling Periods 4-78	5-78	6-78	7-78	8-78	11-78	3-79
Natica clausa	moon-shell	X	X	X	X			X
Fusitrition oregonensis	Oregon tirton		X	X	X	X	X	X
Trophonopsis smithi	gastropod				X			
Nucella lamellosa	frilled dogwinkle	X	X		X	X	X	
Buccinum spp.	snail		X					
Buccinum plectrum	Plectrum Buccinum				X	X		X
Clione limacina	pteropod	X						
Octopus spp.	octopus				X			
Dorididae	nudibranch	X						X
Gammaridae	amphipod		X					X
Balanus spp.	barnacle	X						X
Balanus crenatus	barnacle			X	X			
Balanus rostratus	barnacle				X			
Balanus nubilis	barnacle	X						
Rocinela augustata	isopoda				X			
Caprella spp.	amphipod				X			
Pandalus borealis	pink shrimp		X	X	X	X	X	X
Pandalus goniurus	humpy shrimp	X		X				
Pandalus platyceros	spot shrimp	X			X		X	
Pandalus hypsinotus	coon-stripe shrimp	X		X	X		X	X
Pandalopsis dispar	side-stripe shrimp				X		X	
Spirontocaris lamellicornis	shrimp					X		X
Spirontocaris arcuata	shrimp						X	
Heptacarpus brevirostris	shrimp			X				
Heptacarpus tridens	shrimp	X						
Eualus suckleyi	shrimp				X	X		
Crangon septemspinosa	gray or sand shrimp		X			X	X	
Crangon dalli	gray or sand shrimp	X	X	X	X	X	X	X
Crangon resima	gray or sand shrimp						X	
Crangon communis	gray or sand shrimp				X			
Crangon munita	gray or sand shrimp	X						
Sclerocrangon boreas	shrimp					X		
Argis lar	rock shrimp	X	X	X			X	
Argis dentata	rock shrimp	X	X	X	X	X		X
Argis crassa	rock shrimp			X				
Pagurus ochotensis	hermit crab	X	X	X	X	X	X	X
Pagurus aleuticus	hermit crab		X		X		X	X
Pagurus capillatus	hermit crab	X	X		X	X	X	
Pagurus kennerlyi	hermit crab	X			X	X		X
Pagurus hirsutiusculus hirsutiusculus	hermit crab		X					
Elassochirus tenuimanus	hermit crab	X	X	X		X	X	X
Ellasochirus gilli	hermit crab				X			X
Elassochirus cavimanus	hermit crab					X		
Labidochirus splendescens	hermit crab		X	X	X	X		X
Paralithodes camtschatica	red king crab		X	X	X	X	X	X
Rhinolithodes wosnessenskii	crab				X		X	
Cryptolithodes sitchensis	helmet crab					X		
Oregonia gracilis	decorator crab	X	X	X	X	X	X	X
Hyas lyratus	lyre crab	X	X		X	X	X	
Chionoecetes bairdi	snow crab	X	X	X	X	X	X	X
Pugettia gracilis	kelp crab			X		X		
Cancer magister	dungeness crab		X	X	X	X	X	X
Cancer oregonensis	crab	X	X		X	X		X
Telmessus cheiragonus	hairy crab		X	X	X	X		
Ectoprocta	moss animal				X		X	
Microporina spp.	moss animal	X			X			X
Heteropora spp.	moss animal	X						
Flustridae	moss animal						X	
Flustrella gigantea	moss animal	X			X			X
Hemithiris psittacea	brachiopod				X			
Terebratalia transversa	brachiopod				X	X		

TABLE VIII

CONTINUED

Taxon	Common Name	Sampling Periods						
		4-78	5-78	6-78	7-78	8-78	11-78	3-79
Terebratalina unguicula	brachiopod	X						
Henricia spp.	sea star		X					
Henricia leviuscula	blood star		X		X	X		
Pteraster tesselatus	slime star		X		X			
Crossaster papposus	rose star	X	X		X	X	X	
Solaster spp.	sun star						X	X
Solaster stimpsoni	sun star		X		X			
Solaster dawsoni	sun star			X				
Solaster endeca	sun star				X			
Evasterias troschelii	sea star	X	X	X		X	X	
Evasterias echinosoma	sea star			X				
Stylasterias forreri	sea star		X					
Pycnopodia helianthoides	sunflower star	X	X	X	X	X	X	X
Asterias amurensis	sea star				X			
Leptasterias hexactis	sea star				X			
Orthasterias koehleri	sea star				X		X	X
Lethasterias nanimensis	sea star						X	
Echinarachnius parma	sand dollar	X	X	X	X	X	X	
Strongylocentrotus dorebachiensis	green urchin	X	X	X	X	X	X	X
Strongylocentrotus purpuratus	purple urchin		X					
Ophiuria sarsi	brittle star			X	X	X		
Ophiopholis sp.	brittle star	X						
Ophiopholis aculeata	brittle star				X			
Parastichopus californicus	sea cucumber			X	X			
Cucumaria spp.	sea cucumber			X	X			
Urochordata	tunicate	X		X	X	X	X	X
Styelidae	tunicate	X						
Cnemidocarpa rhizopus	tunicate	X	X	X	X	X	X	X
Pelonaria corrugata	tunicate					X		
Halocynthia aurantium	tunicate - sea peach	X						
Salpidae	tunicate			X				

of the try net aboard the *Yankee Clipper* was restricted to stations in less than 73 m of water due to the loss of the trawl winch on the preceding cruises (May 1978). The try net had to be deployed via the use of a capstan and 5/8 inch polyethylene line. Several unsuccessful attempts to sample stations deeper than 73 m were made. Of the five tows taken aboard the *Commando*, two were taken at depths of 174-201 m, stations 7 and 8 in Area I. These two tows yielded a total of 840 *Chionoecetes bairdi* and 22 *Paralithodes camtschatica*. Approximately 65-75% of the *C. bairdi* were relatively soft; most had formed a new exoskeleton and were nearing ecdysis. Several of the *P. camtschatica* were also in this condition. The mean epifaunal invertebrate biomass for all stations was 7.10 g/m^2. Dominant phyla from all stations were Arthropoda (83.4%) and Echinodermata (15.6%). *Chionoecetes bairdi* (78.8%) and *Pycnopodia helianthoides* (14.9%) were the most important arthropods and echinoderms, respectively.

July 1978

Nineteen stations were successfully sampled in Izhut Bay in July. The try net was used at 15 stations and the otter trawl was used at four stations. The mean invertebrate biomass was 2.74 g/m^2. Dominant taxa, in terms of percent biomass, were arthropods (58.7%), specifically, *Chionoecetes bairdi* (30%) and *Pandalus borealis* (12.3%), and echinoderms (33.3%), specifically, *Pycnopodia helianthoides* (26.8%).

The greatest diversity occurred southwest of Pillar Cape in Area I at station 585 where approximately 62 species of invertebrates were taken. In Saposa Bay, with the exception of the sea anemone, *Metridium senile*, both tows contained dead and decaying invertebrate and plant material. The strong odor of H_2S in the black mud was present in both tows. Of the four tows taken by otter trawls, two (Area I, stations 8 and 9) were taken at depths of 87 to 189 m. These two tows yielded 350 *Chionoecetes bairdi*. Eighteen *Paralithodes camtschatica* came from station 9. Stations 557 of Area III and 526 and 527 of Area II yielded the largest catches of pink shrimp.

August 1978

A total of 15 successful tows were made in Izhut Bay in August, 12 with the try net and three with the otter trawl. The mean invertebrate biomass was 3.41 g/m^2. Arthropods and echinoderms contributed most to the biomass with 64.7% and 32.9% respectively. Pandalid shrimps, specifically *Pandalus borealis* (44.8%) dominated the arthropod biomass. *Chionoecetes bairdi* contributed 13.9% of the biomass. Station 557 of Area III yielded the largest catch of pink shrimp (200 kg). Stations 6 and 8 of Area I were important *C. bairdi* stations. Important echinoderms were the sea stars, *Pycnopodia helianthoides* (26.7%) and *Evasterias troschelii* (5.2%).

Stations in Saposa Bay and Kitoi Bay were nearly devoid of living organisms.

Large concentrations of the Pacific sand lance *Ammodytes hexapterus*, were noted in most portions of Izhut Bay.

November 1978

November sampling in Izhut Bay yielded 15 successful stations, 11 with try net and four with otter trawl. Two Saposa Bay stations were inaccessible due to the large size of the *Commando*. The mean invertebrate biomass was 2.16 g/m^2. The biomass was again dominated by arthropods (56.9%) and echinoderms (40.3%). Major arthropods were *Chionoecetes bairdi* (44.7%) and *Cancer magister* (10.7%). Most *C. bairdi* came from station 7 of Area I. *Pycnopodia helianthoides* again dominated the echinoderms with 38.8% of the biomass.

March 1979

Benthic trawling in Izhut Bay during March 1979 was successfully accomplished *via* the R/V *Commando* at 13 stations; nine *via* a try net trawl and 4 *via* a commercial otter trawl. The mean epifaunal invertebrate biomass for all stations was 9.52 g/m^2. Ninety percent of the biomass consisted of crustaceans with the pink shrimp, *Pandalus borealis*, contributing 41.2% of the biomass and the snow crab, *Chionoecetes bairdi*, contributing 39.8% of the biomass. The largest catches of pink shrimp and snow crab came from a new station, Station 679. At this station 344.6 kg of shrimp and 280.0 kg of snow crab were taken in a 25 minute tow via the otter trawl.

Stomachs of snow crab and pink shrimp were preserved for laboratory examination.

Kiliuda Bay (Tables III-VII, IX; Appendix A, Figure 2)

April 1978

Only six try net stations were successfully sampled in Kiliuda Bay in April. Five stations were less than 36 m deep and one was at approximately 100 m. The mean invertebrate biomass was 2.04 g/m^2. Arthropods (90.4% of the biomass), mainly *Paralithodes camtschatica* (72.9%), made up the majority of the biomass. The majority of king crabs came from Shearwater and Santa Flavia Bay at stations 576, 578, 579 and 580.

June 1978

Successful stations sampled in Kiliuda Bay in June totaled eight, five with try net and three with otter trawl. The mean invertebrate biomass was 3.68 g/m^2. Only commercially-important invertebrates were recorded. *Paralithodes camtschatica* and *Chionoecetes bairdi* made up 72.9% and 26.4% of the mean invertebrate biomass, respectively. Stations 3 and 4 of Area I yielded the greatest number of *P. camtschatica*. The majority (~85%) of *C. bairdi* greater than 160 mm in carapace width were soft-shelled crabs which had recently undergone ecdysis. The highest catch of *C. bairdi* was 55.6 kg in Area I, station 5.

July 1978

July sampling in Kiliuda Bay yielded ten successful stations; seven with try net and three with otter trawl. The mean invertebrate biomass was 2.23 g/m^2. Arthropods were the leading group. *Paralithodes camtschatica* and *Chionoecetes bairdi* accounted for 48.2% and 23.3% of

TABLE IX

INVERTEBRATES TAKEN BY TRAWL IN KILIUDA BAY, 1978-79

X = Taxon Collected

Taxon	Common Name	Sampling Periods					
		4-78	6-78	7-78	8-78	11-78	3-79
Porifera	sponge	X					
Suberites suberea	sponge			X		X	X
Hydrozoa	hydroid					X	X
Cyanea capillata	jelly fish			X			
Metridium senile	sea anemone			X	X		X
Polychaeta	segmented worm			X			
Polynoidae	segmented worm			X			
Harmothoe multisetosa	segmented worm	X					
Eunoe depressa	segmented worm					X	X
Peisidice aspera	segmented worm	X					
Nereidae	segmented worm						X
Cheilonereis cyclurus	segmented worm					X	
Crucigera irregularis	segmented tube worm	X					
Crucigera zygophora	segmented tube worm	X				X	
Serpulidae	segmented tube worm						X
Mopalia swanii	chiton	X					
Mopalia mucosa	chiton						X
Nucula tenuis	soft nut clam	X					
Modiolus modiolus	northern horse mussel	X				X	
Yoldia amygdalea	almond *Yoldia*			X	X	X	
Chlamys spp.	scallop					X	
Chlamys rubida	Hind's scallop	X		X	X		X
Pecten caurinus	weathervane scallop	X		X	X	X	
Pododesmus macrochisma	sea jingle	X		X	X	X	X
Clinocardium ciliatum	Iceland cockle			X			
Clinocardium nuttallii	Nuttall's cockle			X			
Cyclocardia crassidens	cockle	X					
Serripes groenlandicus	Greenland cockle			X	X	X	
Macoma spp.	clam				X	X	
Macoma carlottensis	clam			X			
Tellina nuculoides	Salmon Tellin				X		
Hiatella arctica	Arctic nestler clam	X		X	X	X	X
Puncturella galeata	helmet Puncturella	X		X	X		X
Collisella ochracea	limpet	X			X		
Cryptobranchia alba	limpet	X					
Lepata caeca	northern blind limpet						X
Margarites pupillus	puppet Margarite	X					
Margarites costalis	northern rosy Margarite						X
Lacuna variegata	variegated Lacuna	X					
Trichotropis cancellata	cancellate hairy-shell	X					
Fusitriton oregonensis	Oregon triton	X		X	X	X	X
Trophonopsis lasius	sandpaper Trophon				X		X
Nucella lamellosa	frilled dogwinkle				X	X	
Neptunea lyrata	common northwest Neptune	X		X	X	X	X
Neptunea heros	snail				X		
Admete couthouyi	common northern Admete				X		
Octopus sp.	octopus			X	X		
Clione limacina	pteropod	X					
Balanus nubilis	acorn barnacle	X					
Balanus crenatus	acorn barnacle			X			
Balanus nostratus	acorn barnacle			X			
Pandalus spp.	shrimp				X		X
Pandalus borealis	pink shrimp	X		X		X	X
Pandalus goniurus	humpy shrimp	X				X	X
Pandalus platyceros	spot shrimp	X			X		
Pandalus hypsinotus	coon-stripe shrimp	X		X		X	X
Pandalus danae	dock shrimp			X			
Pandalopsis dispar	side-stripe shrimp						X
Spirontocaris lamellicornis	shrimp			X			
Lebbeus groenlandica	shrimp	X					X
Eualus suckleyi	shrimp	X		X			

TABLE IX

CONTINUED

Taxon	Common Name	Sampling Periods					
		4-78	6-78	7-78	8-78	11-78	3-79
Eualus macilenta	shrimp	X					
Heptacarpus brevirostris	shrimp	X					
Crangon spp.	gray or sand shrimp				X	X	X
Crangon dalli	gray or sand shrimp	X		X	X		X
Crangon communis	gray or sand shrimp	X		X			
Crangon munita	gray or sand shrimp	X					
Sclerocrangon boreas	shrimp	X					
Argis spp.	rock shrimp					X	
Argis lar	rock shrimp	X				X	
Argis dentata	rock shrimp	X		X	X	X	X
Paracrangon echinata	shrimp	X					
Pagurus spp.	hermit crab			X			
Pagurus ochotensis	hermit crab	X		X	X	X	X
Pagurus capillatus	hermit crab	X		X	X	X	X
Pagurus aleuticus	hermit crab			X		X	X
Elassochirus tenuimanus	hermit crab	X		X	X	X	X
Ellassochirus cavimanus	hermit crab						X
Labidochirus splendescens	hermit crab				X	X	
Paralithodes camtschatica	red king crab	X	X	X	X	X	X
Oregonia gracilis	decorator crab	X		X	X	X	
Hyas lyratus	Lyre crab	X		X	X	X	X
Chionoecetes bairdi	snow crab	X	X	X	X	X	X
Cancer magister	dungeness crab		X	X	X	X	X
Cancer oregonensis	crab			X			
Pugettia gracilis	kelp crab	X		X	X	X	
Telmessus cheiragonus	hairy crab	X		X	X		
Ectoprocta	moss animal						X
Flustridae	moss animal	X					
Flustrella gigantea	moss animal			X			
Solaster stimpsoni	sun star				X		
Dermasterias imbricata							X
Evasterias troschelii	sea star				X	X	X
Leptasterias spp.	sea star	X					
Orthasterias koehleri	sea star			X		X	
Pycnopodia helianthoides	sunflower star	X			X		X
Strongylocentrotus drosbachiensis	green urchin	X			X	X	X
Strongylocentrotus purpuratus	purple urchin						X
Parastichopus californicus	sea cucumber	X		X	X		X
Cucumaria spp.	sea cucumber						X
Urochordata	tunicate	X		X			

BEST DOCUMENT AVAILABLE

the invertebrate biomass, respectively. Stations 1 and 4 of Area I and stations 579 and 580 of Area IV yielded the greatest catch of *P. camtschatica*. Large catches of *C. bairdi* came from stations 579, 580 and 6. The cnidarian, *Metridium senile*, also made up 12.1% of the biomass.

August 1978

A total of nine stations were successfully sampled in Kiliuda Bay in August. Six stations were sampled by try net and three stations were sampled by otter trawl. The mean invertebrate biomass was 4.69 g/m^2. The biomass was dominated by arthropods (96.9%), specifically, *Pandalus borealis* (69.3%), *Chionoecetes bairdi* (13.4%), and *Paralithodes camtschatica* (11.3%). Large catches of *C. bairdi* came from Areas I and IV, stations 2 and 579 respectively. Stations 2 and 5 in Area I yielded large catches of *P. camtschatica*. Most *P. borealis* came from station SHR. Station 5 yielded high numbers of the large Pacific cod *Gadus macrocephalus* and walleye pollock *Theragra chalcogramma*.

November 1978

November sampling in Kiliuda Bay yielded eight successful stations; six with try net and two with otter trawl. One otter trawl site and one try net station were not sampled due to large numbers of "stored" king crab pots and "fishing" dungeness crab pots. The mean invertebrate biomass was 4.95 g/m^2, with arthropods again dominating the biomass (96.1%). Leading species were *Pandalus borealis* (58.1%), *Paralithodes camtschatica* (24.4%), and *Chionoecetes bairdi* (7.8%). Most shrimps were taken from Area I at stations SHR and 5. Important *P. camtschatica* stations were 7 and SHR. Snow crabs were mainly taken at stations 5 and 7.

March 1979

A total of eight stations were successfully occupied in Kiliuda Bay in March 1979; five with a try net and 3 with a commercial otter trawl. The mean epifaunal invertebrate biomass for all stations was 2.12 g/m^2. The majority of the biomass consisted of arthropods (85.9%), mainly the red king crab, *Paralithodes camtschatica*, (52.4%) and the snow crab (8.7%). The largest catch of king crab occurred in a ten minute try net tow at station 579 where 56 crab (mainly ovigerous females) weighed 66.4 kg.

Stomach contents of king crab and snow crab were preserved for laboratory examination.

Kodiak Shelf (Tables X, XI; Appendix A; Figures 4 and 5)

March 1978

In March 1978, 16 stations were occupied on the continental shelf by the *Miller Freeman*; epifauna was enumerated at 12 stations. The mean invertebrate biomass was low, 0.47 g/m^2. The highest biomass station was station 18 where the biomass was 1.02 $g/^2$. The major phyla were Echinodermata (37.1% of the biomass), Arthropoda (30.8%), and Mollusca (28.0%). Leading echinoderms were the sea star, *Dipsacaster borealis* (24.7%), the sea urchin, *Strongylocentrotus* spp. (10.2%), and the sea star, *Diplopteraster multipes* (2.2%). Largest catches of *Diplopteraster* came from stations 12 and 26. Important arthropods were *Chionoecetes bairdi* and *Paralithodes camtschatica* which made up 24.6% and 5.0% of the total invertebrate biomass, respectively. Highest catches of *Chionoecetes* came from stations 6 and 7. Dominant molluscs were the snail, *Fusitriton oregonensis* (14.5%), the snail, *Neptunea lyrata* (6.9%), and *Octopus* sp. (4.4%).

Fish and crab were collected for examination of stomach content from 5 stations and are presented in the feeding section of this report.

June-July 1978

In June-July 1978, 16 stations were occupied by the *Miller Freeman* on the Kodiak continental shelf. These stations were different from those occupied in March. One station, station 2, was not considered quantitative because the net was torn, however, fish stomachs were examined from this station. The mean invertebrate biomass was 3.94 g/m^2. Arthropods made up 80.5% of the biomass. *Paralithodes*

BEST DOCUMENT AVAILABLE

TABLE X

PERCENT BIOMASS COMPOSITION OF THE LEADING INVERTEBRATE SPECIES COLLECTED ON THE KODIAK SHELF

March 1978

Phylum	% Biomass of All Phyla	Leading Taxa	% Biomass of Phylum	% Biomass of All Phyla
Echinodermata	41.1	*Dipsacaster borealis*	60.1	24.7
		Strongylocentrotus spp.	24.8	10.2
		Diplopteraster multipes	5.4	2.2
		Totals	90.3	37.1
Arthropoda	30.8	*Chionoecetes bairdi*	79.9	24.6
		Paralithodes camtschatica	16.2	5.0
		Totals	96.1	29.6
Mollusca	28.0	*Fusitriton oregonensis*	51.7	14.5
		Neptunea lyrata	24.8	6.9
		Octopus sp.	15.6	4.4
		Totals	92.1	25.8
Total	99.9			

June-July 1978

Phylum	% Biomass of All Phyla	Leading Taxa	% Biomass of Phylum	% Biomass of All Phyla
Arthropoda	80.5	*Paralithodes camtschatica*	50.9	41.0
		Chionoecetes bairdi	42.4	34.1
		Pandalus borealis	5.2	4.2
		Totals	98.5	79.3
Cnidaria	8.8	*Ptilosarcus gurneyi*	40.4	3.6
		Metridium spp.	28.6	2.5
			26.0	2.3
		Totals	95.0	8.4
Echinodermata	7.9	*Echinarachnius parma*	47.1	3.7
		Holothuroidea	41.2	3.3
		Totals	88.3	7.0
Total	97.2			

TABLE X

CONTINUED

February 1979

Phylum	% Biomass of All Phyla	Leading Taxa	% Biomass of Phylum	%Biomass of All Phyla
Arthropoda	80.6	*Chionoecetes bairdi*	79.1	63.7
		Paralithodes camtschatica	17.6	14.2
		Pandalus borealis	2.0	1.6
		Totals	98.7	79.5
Mollusca	14.8	*Modiolus modiolus*	94.8	14.1
Echinodermata	2.9	*Gorgonocephalus caryi*	99.9	2.9
Urochordata	1.1	*Halocynthia aurantium*	97.2	1.1
Total	99.4			

TABLE XI

INVERTEBRATES TAKEN BY TRAWL ON THE KODIAK SHELF, 1978-79

X = Taxon Collected

Taxon	Common Name	Sampling Periods 3-78	6-78	2-79
Porifera	sponge		X	
Hydrozoa	hydroid			X
Anthozoa	sea anemone, sea pea	X		
Stylatula gracile	sea pen	X	X	
Ptilosarcus gurneyi	sea pen		X	X
Actiniidae	sea anemone		X	
Metridium senile	sea anemone		X	
Polynoidae	segmented worm - scale worm	X		
Nereidae	segmented worm	X		
Aphrodita japonica	segmented worm	X		
Modiolus modiolus	northern horse mussel		X	X
Pecten caurinus	weathervane scallop	X		
Chlamys spp.	scallop		X	
Chlamys rubida	scallop			X
Pododesmus macrochisma	sea jungle	X	X	X
Astarte montagui	Montagu's Astarte		X	
Astarte esquimalti	clam		X	
Cyclocardia crassidens	cockle		X	
Clinocardium fucanum	Fucan cockle		X	
Serripes groenlandicus	Greenland cockle			X
Fusitriton oregonensis	Oregon triton	X	X	X
Nucella lamellosa	frilled dogwinkle		X	
Beringius kennicotti	Kennicott's Buccinum	X	X	X
Neptunea lyrata	common northwest Neptune	X	X	X
Neptunea pribiloffensis	Pribiloff Neptune	X		
Pyrolofusus harpa	left-handed Buccinum	X		
Arcteomelon stearnsii	Stearn's Volute	X		
Leucosyrinx circinata	snail	X		
Natica spp.	moon snail			X
Octopus spp.	octopus	X		X
Pandalus borealis	pink shrimp	X	X	X
Pandalus goniurus	humpy shrimp		X	
Pandalus hypsinotus	coon-stripe shrimp		X	X
Pandalopsis dispar	side-stripe shrimp	X	X	X
Hippolytidae	shrimp		X	X
Eualus biunguis	shrimp		X	
Heptacarpus cristata	shrimp		X	
Crangon spp.	gray or sand shrimp		X	X
Crangon dalli	gray or sand shrimp		X	
Cragnon communis	gray or sand shrimp		X	
Argis spp.	rock shrimp			X
Argis lar	rock shrimp		X	
Argis dentata	rock shrimp		X	
Pagurus spp.	hermit crab		X	
Pagurus ochotensis	hermit crab	X	X	X
Pagurus aleuticus	hermit crab	X	X	X
Pagurus capillatus	hermit crab	X	X	X
Pagurus kennerlyi	hermit crab		X	
Pagurus hirsutiusculus hirsutiusculus	hermit crab		X	
Pagurus confragosus	hermit crab	X	X	
Pagurus cornutus	hermit crab	X		
Elassochirus tenuimanus	hermit crab		X	
Elassochirus cavimanus	hermit crab		X	X
Elassochirus gilli	hermit crab	X	X	X
Placetron wosnessenskii	scale crab		X	
Paralithodes camtschatica	red king crab	X	X	X
Chionoecetes bairdi	snow crab	X	X	X
Oregonia gracilis	decorator crab		X	

TABLE XI

CONTINUED

Taxon	Common Name	Sampling Periods 3-78	Sampling Periods 6-78	Sampling Periods 2-79
Hyas lyratus	Lyre crab		X	
Cancer magister	dungeness crab			X
Cancer oregonensis	crab		X	
Telmessus cheiragonus	hairy crab		X	
Brachiopoda	lamp shell		X	
Terebratalia transversa	lamp shell		X	X
Dipsacaster borealis	sea star	X		
Gephyreaster swifti	sea star	X		
Hippasterias spinosa	sea star	X		
Pseudarchaster parelii	sea star	X		
Henricia spp.	sea star	X		
Henricia leviuscula	blood star		X	
Diplopteraster multipes	sea star	X		
Pteraster tesselatus	sea star		X	X
Crossaster papposus	rose star		X	X
Lophaster furcilliger	sea star	X		
Solaster spp.	sun star	X		
Solaster dawsoni	sun star		X	
Asterias amurensis	sea star	X		
Evasterias spp.	sea star	X		
Leptasterias polaris	sea star	X		
Pycnopodia helianthoides	sunflower star		X	
Echinarachnius parma	sand dollar		X	
Brisaster townsendi	heart urchin	X		
Strongylocentrotus spp.	sea urchin	X		
Strongylocentrotus droebachiensis	green urchin		X	X
Strongylocentrotus purpuratus	purple urchin	X		
Ophiuroidea	brittlestar, basket star		X	
Gorgonocephalus caryi	basket star	X	X	X
Ophiopholis aculeata	brittlestar	X	X	X
Ophiura sarsi	brittlestar		X	X
Holothuroidea	sea cucumber		X	
Molpadia spp.	sea cucumber		X	
Molpadia oolitica	sea cucumber			X
Cucumaria spp.	sea cucumber		X	
Urochordata	tunicate	X		X
Halocynthia aurantium	sea peach			X

camtschatica and *Chionoecetes bairdi* accounted for 50.9% and 42.4%, respectively, of the arthropod biomass and 41% and 34%, respectively, of the total biomass. *Paralithodes camtschatica* was present at nine stations. Highest catches of *P. camtschatica* came from stations 7, 8 and 9. The king crab catch at stations 7 and 8 mainly consisted of ovigerous females (78%). King crabs at station 9 were mainly ovigerous females (48%) and adult males (46%).

Chionoecetes bairdi was present at 13 stations and large catches came from stations 7, 12 and 13. *Pandalus borealis* also made up 4.2% of the total biomass. *Pandalus borealis* was present at seven stations (Stations 7, 8, 10, 11, 13 and 14) but was most abundant at station 13.

The second leading phylum was Cnidaria, contributing 8.8% of the biomass. Leading cnidarians were the sea pen *Ptilosarcus gurneyi* (3.6% of the biomass), the sea anemone *Metridium* spp. (2.5%), and Actiniidae (2.3%). The largest catch of *Ptilosarcus* came from station 1.

Echinoderms ranked third in biomass (7.9%). Dominant echinoderms were the sand dollar, *Echinarachnius parma*, and sea cucumbers, Holothuroidea, which contributed 3.7% and 3.3% of the total biomass, respectively. *Echinarachnius parma* was mainly taken at station 1.

Fish, crab and shrimp were collected for examination of stomach contents and are presented in the feeding section of this report.

February 1979

Trawling activities *via* the NOAA ship *Miller Freeman* on the Kodiak continental shelf in February 1979 yielded 14 successful stations. One station, station 3, was not considered quantitative because the net was torn, however, fish stomachs were examined from this station. The mean epifaunal invertebrate biomass for all stations was 3.15 g/m^2. The biomass was dominated by the phylum Arthropoda (80.5% of the biomass), and followed by the phylum Mollusca (14.8%). The snow crab, *Chionoecetes bairdi*, and the king crab, *Paralithodes camtschatica*, dominated the arthropods with 63.7% and 14.2% of the total biomass, respectively. The mussel, *Modiolus modiolus*, was the most important mollusc. This bivalve comprised 14.0% of the total biomass.

Snow crab were found at 14 stations. Stations with high biomass of snow crab were 12, 11, 10, 7, 8, 14 and S5. Station 7 yielded the greatest biomass of snow crab with 185 individuals at 139.5 kg.

Seven stations contained king crab, and the highest biomass occurred at station 7 with 75 individuals (65 ovigerous females) at 117.1 kg. Pink shrimp were present at six stations, comprised 1.6% of the biomass, and were most abundant at station 14.

The mussel, *Modiolus modiolus*, was found at only one station, station S2, where 1150 individuals weighed 172.5 kg.

Fish, crab and shrimp were collected for examination of stomach contents and are presented in the feeding section of this report.

PIPE DREDGE DATA: DISTRIBUTION - RELATIVE ABUNDANCE

Kodiak Shelf (Table XII, Appendix A; Figure 5)

June-July 1978 and February 1979

Pipe dredge data were collected on the Kodiak Shelf in June-July 1978 and February 1979 to aid in the identification of fish and invertebrate stomach contents. As a qualitative sampling device only relative abundances of invertebrate species were obtained. Bivalve molluscs, specifically *Axinopsida serricata, Psephidia lordi, Nucula tenuis, Nuculana fossa,* and *Macoma* spp., dominated at most stations. These bivalve species are common prey to many invertebrate and fish predators on the Kodiak Shelf. Any relationship between the relative abundance of these pipe-dredge species and the species consumed by various predators will be discussed in the Food Studies section of this report.

TABLE XII

DOMINANT TAXA BY STATION COLLECTED *VIA* PIPE DREDGE ON THE KODIAK SHELF

June-July 1978			February 1979		
Station 1	No.	%			
Ampelisca birulai	8	16.0			
Echinarachnius parma	5	10.0	No data obtained at Station 1		
Macoma spp.	4	8.0			
Ophiura sarsi	4	8.0			
Station 22					
Glycera capitata	3	33.0	No data obtained at Station 22		
Elassochirus tenuimanus	2	22.0			
Station 44					
Macoma lipara	24	29.3			
Cucumaria sp.	22	26.8	No data obtained at Station 44		
Balanus crenatus	8	9.8			
Nuculana fossa	6	7.3			
Station 4			**Station 4**	No.	%
Macoma spp.	17	19.3	*Axinopsida serricata*	200	37.5
Cucumaria spp.	12	13.6	*Psephidia lordi*	100	18.8
Onuphis iridescens	11	12.5	*Macoma* spp.	100	18.8
Glycera capitata	10	11.4	*Nuculana fossa*	34	6.4
			Nucula tenuis	24	4.5
Station 5			**Station 5**		
Nuculana fossa	5	25.0	*Eudorella emarginata*	50	29.1
Pinnixa occidentalis	3	15.0	*Myriochele heeri*	20	11.6
			Echiurus spp.	20	11.6
			Pinnixa occidentalis	16	9.3
			Nuculana fossa	10	5.8
Station 7			**Station 7**		
Axinopsida serricata	200	52.5	*Axinopsida serricata*	500	87.0
Rhynchocoela	20	5.2	*Nucula tenuis*	35	6.1
Heteromastus filiformis	20	5.2	*Yoldia thraciaeformis*	9	1.6
Macoma moesta	20	5.2			
Praxillella affinis	15	3.9			
Nucula tenuis	15	3.9			
Macoma calcarea	12	3.1			

TABLE XII

CONTINUED

June-July 1978			February 1979		
Station 8	**No.**	**%**	**Station 8**	**No.**	**%**
Axinopsida serricata	100	38.9	*Nucula tenuis*	320	57.5
Nucula tenuis	50	19.5	*Axinopsida serricata*	70	12.6
Thysanoessa inermis	40	15.6	*Nuculana fossa*	70	12.6
Haploscoloplos panamensis	10	3.9	*Yoldia thraciaeformis*	45	8.1
Yoldia montereyensis	10	3.9	*Macoma* spp.	22	3.9
Station 9			**Station 9**		
Axinopsida serricata	500	56.2	*Axinopsida serricata*	300	35.1
Macoma calcarea	100	11.2	*Nucula tenuis*	180	21.1
Eudorella emarginata	50	5.6	*Myriochele heeri*	100	11.7
Nucula tenuis	45	5.1	*Macoma* spp.	70	8.2
Nuculana fossa	45	5.1	*Pinnixa occidentalis*	60	7.0
Haploscoloplos panamensis	30	3.4	*Nuculana fossa*	50	5.8
			Travisia forbesii	22	2.6
Station 10			**Station 10**		
Axinopsida serricata	15	50.0	*Pinnixa occidentalis*	250	69.1
Macoma spp.	5	16.7	*Axinopsida serricata*	50	13.8
Echiuridae	5	16.7	*Echiurus echiurus*	30	8.3
			Yoldia amygdalea	13	3.6
Station 11			**Station 11**		
Echiuridae	300	95.2	*Axinopsida serricata*	35	70.0
Heteromastus filiformis	4	1.3	*Pinnixa occidentalis*	3	6.0
Yoldia amygdalea	4	1.3	*Macoma* spp.	2	4.0
Axinopsida serricata	4	1.3	*Yoldia amygdalea*	2	4.0
Station 12			**Station 12**		
Sarcodina Rhizopodea	1000	53.9	*Nucula tenuis*	43	20.2
Echiuridae	500	27.0	*Axinopsida serricata*	40	18.8
Axinopsida serricata	200	10.8	*Macoma* spp.	35	16.4
Macoma spp.	50	2.7	*Yoldia amygdalea*	21	9.9
Cylichna alba	30	1.6	*Nuculana fossa*	10	4.7
			Ophiuroidea	10	4.7
Station 13					
Axinopsida serricata	31	47.7			
Heteromastus filiformis	10	15.4			
Sarcodina Rhizopodea	5	7.7	No data obtained at Station 13		
Nephtys punctata	5	7.7			
Macoma spp.	5	7.7			

TABLE XII

CONTINUED

June-July 1978			February 1979		
Station 14	**No.**	**%**	**Station 14**	**No.**	**%**
Cerebratulus spp.	1	16.7	*Axinopsida serricata*	10	37.0
Amphicteis gunneri	1	16.7	*Nephtys punctata*	8	29.6
Nuculana fossa	1	16.7	*Yoldia thraciaeformis*	3	11.1
Axinopsida serricata	1	16.7	*Psephidia lordi*	3	11.1
Clinocardium ciliatum	1	16.7			
Macoma calcarea	1	16.7			
			Station 3		
			Macoma obliqua	6	28.6
No data obtained at Station 3			*Ophiopholis aculeata*	5	23.8
			Golfingia vulgaris	3	14.3
			Station 23		
			Psephidia lordi	1800	86.6
			Olivella baetica	85	4.1
No data obtained at Station 23			*Suavodrillia kennicotti*	75	3.6
			Glycinde picta	30	1.4
			Gammaridae	18	0.9
			Station S2		
			Oregonia gracilis	7	18.9
No data obtained at Station S2			*Cancer oregonensis*	7	18.9
			Ophiopholis aculeata	5	13.5
			Station S3		
			Psephidia lordi	16	16.7
No data obtained at Station S3			*Axinopsida serricata*	15	15.6
			Nuculana fossa	13	13.5
			Myriochele heeri	10	10.4
			Station S5		
			Nuculana fossa	13	15.3
			Myriochele heeri	10	11.8
No data obtained at Station S5			*Yoldia thraciaeformis*	10	11.8
			Psephidia lordi	10	11.8
			Axinopsida serricata	8	9.4

SEDIMENT SWEEP DATA: RELATIVE ABUNDANCE

Near Island Basin (Table XIII; Figure 3)

October 1978

At a water depth of 11 meters, five bottom sweeps, each approximately 2 m long, yielded 1.65 ℓ of fine sandy sediment. Invertebrates present were dominated by 49 juvenile ($\bar{X}$ 14 mm carapace width) snow crab, *Chionoecetes bairdi*, approximately 200 gammarid amphipods, 124 small cockles, *Clinocardium nuttallii*, 100 tiny snails, *Lacuna variegata*, and 100 tiny nestler clams, *Hiatella arctica*. A variety of other invertebrates were also present.

The stomach of juvenile snow crabs were examined for comparison with the potential prey recovered in the sweeps. The latter results are included in the Food Studies section of this report.

May 1979

The October 1978 Near Island Basin sediment sweep site was revisited in May 1979. Approximately 15 m of sediment surface was sampled with the SCUBA-operated sweep and 3.4 ℓ of fine sandy sediment was obtained. The sample included 60 juvenile (30 measurable - $\bar{X}$ 3.42 mm width) and 46 megalopa snow crab, approximately 1000 *Lacuna variegata*, 460 small clams, *Mya priapus*, and 400 gammarid amphipods. A variety of other invertebrates were also present.

REPRODUCTIVE DATA: KING CRAB AND SNOW CRAB

Data on reproduction was limited to observations on the state of ovigerousness of king and snow crabs from the Kodiak Shelf.

King crabs collected during the June-July 1978 cruise totalled 743. The number of females totalled 486, of which 445 (92%) were gravid. All eggs were purple in color indicating relatively early development.

King crabs from the February 1979 cruise totalled 114, of which, 88 (77%) were ovigerous. Most crabs (83) were carrying eggs that had

TABLE XIII

ORGANISMS COLLECTED IN NEAR ISLAND BASIN *VIA* SEDIMENT SWEEP

Taxon	October 30, 1979	May 11, 1979
	Number	
Alcyonaria	10	-
Ammotrypane aulogaster	22	14
Polychaeta (4 species)	-	20
Nucula tenuis	-	24
Psephidia lordi	48	16
Hiatella arctica	100	38
Axinopsida serricata	-	2
Mya priapus	35	460
Spisula polynyma	22	28
Protothaca staminea	31	48
Mytilus edulis	-	2
Serripes groenlandicus	16	2
Clinocardium nuttallii	124	58
Cylichna alba	4	6
Retusa obtusa	-	14
Margarites costalis	-	20
Crepidula nummaria	-	2
Oenopota sp.	11	14
Lacuna variegata	100	1000
Amphissa columbiana	-	2
Trichotropsis insignis	1	-
Olivella baetica	2	-
Clione limacina	-	2
Cumacea (2 species)	1	110
Gammaridae (4 species)	200	400
Ampelisca sp.	8	-
Anonyx sp.	1	-
Crangon septemspinosa	12	30
Sclerocrangon boreas	-	2
Eualus suckleyi	1	-
Pagurus ochotensis	2	2
Pagurus sp.	1	-
Elassochirus tenuimanus	-	2
Chionoecetes bairdi	49	60+40 megalops
Pholis laeta	-	2

advanced to the eyed stage of development. Five mature females were clutchless and had matted pleopods indicating recent hatching of larvae.

The June-July cruise yielded only 170 (14.8%) snow crabs with eggs out of 1150 crabs captured. The majority of the gravid females came from Stations 10 (90 individuals) and 12 (51 individuals). All eggs were bright orange in color indicating recent deposition.

Females with eggs from the February cruise were less abundant than in the June-July period. Only 69 gravid females were observed from three locations; Stations 7, 8 and 10. All eggs were in the eyed stage of development.

FOOD STUDIES

Paralithodes camtschatica (king crab)

A total of 809 king crab digestive tracts were examined in the present study (Table XIV). Food was found in 713 stomachs. Intestine contents are listed in Appendix B, Table I. Crabs were obtained *via* benthic trawling in Izhut Bay, Kiliuda Bay, and the offshore Kodiak shelf, and *via* SCUBA in three shallow, nearshore areas i.e., Near Island Basin, McLinn Island, and Anton Larsen Bay.

Izhut Bay (Figure 1)

June 1978 (Table XV)

King crabs were collected for food analysis in Izhut Bay in June at Stations 7 and 8 of Area I. Twenty-two crabs were taken, of which, 55% were newshell ovigerous females and 36% were newshell males greater than 100 mm in length. Twenty of the crabs were feeding on a total of 19 taxa. The mean percent fullness among crabs containing food was 6.1 ± 8.1%. King crab stomachs were dominated by fishes; 55% by frequency of occurrence (among all stomachs) and 69% by weight. Arthropods, echinoderms, and molluscs accounted for less than 12% of the total food weight.

Food examined from the intestines of Uzhut Bay king crabs was similar to food found in the stomachs.

TABLE XIV

NUMBERS AND LOCATIONS OF KING CRABS EXAMINED FOR FOOD CONTENTS

	Izhut Bay Stations			
	7	8	9	Totals
June 1978	10	12	-	22
July 1978	-	-	18	18
TOTALS	10	12	18	40

	Kiliuda Bay Stations														
	1	2	3	4	5	6	7	576	577	578	579	580	676	SHR	Totals
April 1978	-	-	-	-	-	-	-	14	4	10	5	7	-	7	47
June 1978	-	-	17	34	5	-	-	-	-	1	8	12	-	-	77
July 1978	13	-	-	25	-	3	-	2	2	5	12	6	-	1	69
August 1978	-	17	-	3	12	-	-	-	-	-	5	-	-	6	43
November 1978	-	-	-	-	-	-	31	-	-	-	-	-	-	24	55
March 1979	-	-	-	-	-	-	-	2	3	-	20	8	5	-	38
TOTALS	13	17	17	62	17	3	31	18	9	16	50	33	5	38	329

	Kodiak Shelf Stations										
	1	7	8	9	10	11	12	13	14	23	Totals
June-July 1978	7	33	40	44	16	16	28	8	4	-	196
February 1979	-	10	4	-	-	-	-	-	-	8	22
TOTALS	7	43	44	44	16	16	28	8	4	8	218

Near Island Basin	
May 1978	35
June 1978	32
May 1979	21
TOTAL	88

McLinn Island	
May 1978	49
May 1979	16
TOTAL	65

Anton Larsen Bay	
June 1978	52
May 1979	17
TOTAL	69

TABLE XV

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY
June 1978. Mean depth 184±6 meters

Number Examined: 22

Number Empty: 2

Percent Composition of Crab Classes[1]: 1=9.1%; 2=54.5%; 6=36.4%

Mean Length: 115±11 mm

Mean Weight: 1200±364 g

Mean Percent Fullness[2]: 5.5±7.9%; 6.1±8.1%

Number of Prey Taxa: 19

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Chordata	Pisces (fishes)	55	60	68.6	77.4
Arthropoda	Hippolytidae (shrimp)	4	5	3.2	2.0
	Decapoda	23	25	0.3	0.5
Echinodermata	Ophiuroidea (brittle star)	4	5	6.3	3.2
Mollusca	*Clinocardium ciliatum* (cockle)	14	15	1.4	0.9
Unidentified plant material		32	35	14.1	11.9
Unidentified animal material		23	25	2.9	2.1

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

July 1978 (Table XVI)

The 18 king crabs collected in July at Izhut Bay, Area I, Station 9, were composed of newshell ovigerous females (66.7%) and newshell males greater than 100 mm in length (33.3%). All but one crab contained food. Nine different prey taxa were identified. The mean fullness among crabs containing food was 10.9 ± 10.4%. As in June, the leading prey was fishes; 78% by frequency of occurrence and 92.8% of the total food weight. Molluscan prey accounted for less than 1.2% of the total weight.

Food found in the intestine of Izhut Bay king crabs was similar to food found in the stomachs.

Kiliuda Bay (Figure 2)

April 1978 (Table XVII)

Forty-seven king crabs collected in Kiliuda Bay in April came from Stations 576, 577, 578, 580 and SHR. Only 15 (32%) of the crabs collected contained food. Twenty-four different taxa were identified. The mean fullness of the 47 stomachs was 1.9 ± 8.1%; feeding crabs had a fullness of 6.4 ± 13.8%. The crab class composition was mainly newshell ovigerous females (59.6%) and newshell males greater than 100 mm in length (23.4%). No single prey dominated the stomach contents. The bivalve molluscs *Nuculana* spp., *Clinocardium* spp. and *Nucula tenuis* each made up 4% of the total prey weight. Decapod crustaceans (crabs and/or shrimps) were found in 8% of the crab examined but only accounted for 3.4% of the weight. Barnacles were found in 6% of the crabs examined. Fishes were found in 2% of the crabs and accounted for 7.1% of the weight. Seventy-six percent of the food weight was unidentified animal material.

Food found in the intestines of Kiliuda Bay king crabs was similar to food found in the stomachs.

June 1978 (Table XVIII)

Seventy-seven king crabs collected in Kiliuda Bay in June were of mixed composition i.e., 13% were newshell ovigerous females, 1.3% were newshell

TABLE XVI

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY July 1978. Mean Depth 177 meters

Number Examined: 18

Number Empty: 1

Percent Composition of Crab Classes[1]: 2=66.7%; 6=33.3%

Mean Length: 115±11 mm

Mean Weight: 1217±257 g

Mean Percent Fullness[2]: 10.3±10.4%; 10.9±10.4%

Number of Prey Taxa: 9

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on: Total stomachs	% Freq. Occurrence based on: Stomachs w/food	% by Weight	% by Volume
Chordata	Pisces (fishes)	78	82	92.8	92.2
Mollusca	*Nuculana* sp. (clam)	11	12	0.7	0.6
	Clinocardium spp. (cockle)	11	12	0.4	0.4
	Axinopsida serricata (clam)	6	6	<0.1	0.2
Unidentified plant material		28	29	4.2	4.1

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XVII

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY April 1978. Mean Depth 38.6±30.4 meters

Number Examined: 47

Number Empty: 32

Percent Composition of Crab Classes[1]: 1=4.3%; 2=59.6%; 3=2.1%; 6=23.4%; 7=2.1%; 8=8.5%

Mean Length: 122±21 mm

Mean Weight: 1471±1039 g

Mean Percent Fullness[2]: 2.1±8.2%; 6.4±13.8

Number of Prey Taxa: 24

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on		% by Weight	% by Volume
		Total stomachs	Stomachs w/food		
Mollusca	*Nuculana* spp. (clam)	4	13	2.5	2.2
	Clinocardium spp. (cockle)	6	20	1.1	1.5
	Nucula tenuis (clam)	4	13	0.9	0.8
	Pelecypoda (clam)	15	47	4.2	3.9
Arthropoda	Decapoda	8	27	3.4	1.6
	Balanus spp.	6	20	0.2	0.2
Chordata	Pisces (fishes)	2	7	7.1	7.2
Unidentified animal material		11	33	69.9	76.1
Unidentified plant material		8	27	<0.1	0.3

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XVIII

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY
June 1978. Mean depth 46±25 meters

Number Examined: 77

Number Empty: 5

Percent Composition of Crab Classes[1]: 2=13.0%; 3=1.3%; 4=3.9%; 6=19.5%; 7=59.7%; 8=2.6%

Mean Length: 125±20 mm

Mean Weight: 1925±2413 g

Mean Percent Fullness[2]: 6.9±9.3%; 7.5±9.5

Number of Prey Taxa: 46

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Nuculana* spp. (clam)	45	49	14.2	9.5
	Macoma spp. (clam)	30	32	13.7	12.4
	Pelecypoda (clams)	45	49	1.7	2.6
	Nucula tenuis (clam)	25	27	2.5	2.6
	Clinocardium spp. (cockle)	12	13	1.5	1.1
Anthropoda	*Balanus* spp.[4] (barnacle)	36	39	32.0	28.8
	Decapoda	41	45	6.2	8.0
Chordata	Pisces (fishes)	8	8	8.2	9.5
Annelida	Polychaeta (segmented worms)	22	24	1.6	2.5
Unidentified animal material		31	34	4.7	7.3
Unidentified plant material		31	34	0.9	1.4

---

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

[4] includes some *Balanus crenatus*

males less than 100 mm long, 3.9% were oldshell males less than 100 mm, 19.5% were newshell males greater than 100 mm, 59.7% were oldshell males greater than 100 mm, and 2.6% were very oldshell males greater than 100 mm. All king crabs examined came from seven stations: 3, 4, 5, 576, 578, 579 and 580. Most crabs examined were feeding (94%). A total of 46 different prey taxa were identified. The mean fullness among crabs containing food was 7.5 ± 9.5%. Important prey, in terms of percent of total prey weight, were pelecypod molluscs (clams), specifically, *Nuculana* spp. (14.2%) and *Macoma* spp. (13.7%). Crustaceans were dominated by barnacles, *Balanus* spp., (32.0%) and decapods (6.2%). Fishes also accounted for 8.2% of the prey weight.

Food found in the intestines of Kiliuda Bay king crabs was similar to food found in the stomachs.

July 1978 (Table XIX)

Sixty-nine king crabs were collected in Kiliuda Bay in July at Stations 1, 4, 6, 576, 578, 579, 580 and SHR. The crabs were mainly newshell ovigerous females (58.6%), oldshell males greater than 100 mm in carapace length (18.6%), and newshell males greater than 100 mm (11.4%). All but one crab contained food. The mean percent fullness among feeding crabs was 9.0 ± 9.5%. Seventy different taxa were identified as prey. The most important prey items, in terms of percent of total food weight, were the Arthropoda. Barnacles, mainly *Balanus crenatus*, accounted for more than 50% of the food weight. *Chionoecetes bairdi* occurred in 27% of the stomachs examined but made up only 5.1% of the weight. Another important food group was the Pelecypoda (clams, cockles). The clams *Nuculana* spp. and *Macoma* spp. accounted for 15.8% and 11.1% of the weight, respectively. *Nucula tenuis* and *Clinocardium ciliatum* contributed 4.8% and 2.5% of the weight, respectively. Fishes composed 1.7% of the food weight.

Food from the intestines of these king crabs was similar to food found in the stomachs.

TABLE XIX

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY
July 1978. Mean Depth 52±31 meters

Number Examined: 69

Number Empty: 1

Percent Composition of Crab Classes[1]: 1=8.6%; 2=58.6%; 6=11.4%; 7=18.6%; 8=2.9%

Mean Length: 116±13 mm

Mean Weight: 1338±484 g

Mean Percent Fullness[2]: 8.9±9.5%; 9.0±9.57%

Number of Prey Taxa: 70

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Balanus crenatus* (barnacles)	20	21	37.8	33.9
	Balanus spp. (barnacles)	27	28	10.2	8.5
	Balanus rostratus (barnacles)	4	4	2.6	2.4
	Chionoecetes bairdi (snow crab)	27	28	5.1	6.5
Mollusca	*Nuculana* spp. (clams)	64	66	15.8	12.0
	Macoma spp. (clams)	39	40	11.1	12.0
	Nucula tenuis (clam)	40	41	4.8	5.4
	Clinocardium ciliatum (cockle)	31	32	2.5	3.3
Chordata	Pisces (fishes)	10	10	1.9	2.2

---

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

August 1978 (Table XX)

Forty-three king crabs were collected for food analysis at Stations 2, 4, 5, 579 and SHR. The crabs were mainly composed of newshell males greater than 100 mm in length (44.1%), oldshell males greater than 100 mm (25.6%), and newshell ovigerous females (25.6%. Thirteen of the crabs had empty stomachs. The mean percent fullness among crabs containing food was 2.7 ± 3.5%. Thirty-two different prey taxa were identified. Prey was dominated by pelecypod molluscs, specifically, *Macoma* spp. (48.3% of weight), *Nuculana* spp. (11.4%), and *Nucula tenuis* (7.2%). Decapods occurred in 12% of the stomachs but accounted for only 0.9% of the weight. The sea urchin *Strongylocentrotus droebachiensis* occurred in only 2% of the crabs but accounted for 15.2% of the weight.

Food found in the intestines of Kiliuda Bay king crabs was similar to food found in the stomachs.

November 1978 (Table XXI)

Fifty-five king crabs were collected for food analysis in Area I at Stations 7 and SHR. The crabs were mainly composed of juvenile newshell females (32.7%), newshell ovigerous females (36.4%), and newshell males greater than 100 mm (18.2%). Forty-nine crabs (89% of all crabs examined) contained food. The mean percent fullness among crabs containing food was 8.7 ± 12.8%, and the total identified food taxa was 29. Molluscs and arthropods were the dominant foods. Leading molluscs were the clams *Macoma* spp. (17.8% of the total weight) and *Axinopsida serricata* (4.6%), and gastropods (0.5%). Arthropods were dominated by *Chionoecetes bairdi* (3.2%) and *Pandalus* spp. (17.1%). Fishes composed 5.4% of the prey weight.

Food found in the intestines of Kiliuda Bay king crabs was similar to food found in the stomachs.

March 1979 (Table XXII)

The 38 king crabs collected in Kiliuda Bay in March 1979 came from five stations: 20 at Station 579, 8 at Station 580, 2 at Station 576,

TABLE XX

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY
August 1978. Mean Depth 71±27 meters

Number Examined: 43

Number Empty: 13

Percent Composition of Crab Classes[1]: 1=4.7%; 2=25.6%; 6=44.1%; 7=25.6%

Mean Length: 115±10 mm

Mean Weight: 1245±351 g

Mean Percent Fullness[2]: 1.9±3.2%; 2.7±3.5

Number of Prey Taxa: 32

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	42	60	48.3	40.2
	Nuculana spp. (clam)	23	33	11.4	8.4
	Nucula tenuis	21	30	7.2	8.3
Arthropoda	Decapoda	12	17	0.9	1.2
	Pandalus sp. (shrimp)	2	3	2.4	2.6
Echinodermata	*Strongylocentrotus droebachiensis* (sea urchin)	2	3	15.2	18.1

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

BEST DOCUMENT AVAILABLE

TABLE XXI

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY November 1978. Mean Depth 89.5±10.6 meters

Number Examined: 55

Number Empty: 6

Percent Composition of Crab Classes[1]: 1=32.7%; 2=36.4%; 5=5.5%; 4=3.6%; 6=18.2%; 7=3.6%

Mean Length: 105±14 mm

Mean Weight: 981±416 g

Mean Percent Fullness[2]: 7.8±12.4%; 8.7±12.8

Number of Prey Taxa: 29

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	44	49	17.8	15.5
	Axinopsida serricata (clam)	24	26	4.6	3.9
	Gastropoda (snail)	13	14	0.5	0.6
Arthropoda	*Chionoecetes bairdi* (snow crab)	24	27	3.2	2.7
	Pandalus spp. (shrimp)	4	4	17.1	17.5
Chordata	Pisces (fishes)	7	8	5.4	5.2
Unidentified animal material		78	88	37.8	36.4
Unidentified plant material		7	8	1.2	1.0
Sediment		64	71	0.8	1.3

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XXII

STOMACH CONTENTS OF KINC CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY March 1979. Mean Depth 37±26.5 meters

Number Examined: 38

Number Empty: 8

Percent Composition of Crab Classes[1]: 2=63.2%; 6=36.8%

Mean Length: 110±17 mm

Mean Weight: 1460±649 g

Mean Percent Fullness[2]: 6.9±9.9%; 8.8±10.4

Number of Prey Taxa: 23

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	45	57	25.3	21.3
	Nuculana spp. (clams)	26	33	2.7	2.3
Chordata	Pisces (fishes)	10	13	23.6	24.8
Arthropoda	Unidentified crab	8	10	11.7	12.8
Unidentified animal material		71	90	29.8	31.4
Unidentified plant material		13	17	1.5	1.3

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

3 at Station 577, and 5 at Station 676. The mean percent fullness among the 30 crabs that contained food was 8.8 ± 10.4%. Molluscs were the main identifiable foods. Dominant molluscs were the pelecypods *Macoma* spp. These clams comprised 25.3% of the stomach contents weight and occurred in 45% of the stomachs. *Macoma* spp. was an important food at Station 579, 580, and 576. The protobranch clam *Nuculana* spp. was found in 26% of all stomachs and accounted for 2.7% of the weight. Unidentified fishes and crabs were also common prey yielding 23.6% and 11.7% of the stomach biomass, respectively. A large proportion (29.8% by weight) of the stomach contents was unidentified animal material. Plant material was found in 13% of all stomachs but only accounted for 1.5% of the biomass.

Food found in the intestines of Kiliuda Bay king crabs was similar to food found in the stomachs.

Near Island Basin (Figure 3)

May 1978 (Table XXIII)

In early May 1978, large concentrations of king crabs were located in Near Island Basin adjacent to the Kodiak city boat harbor. The crabs were first sighted from a skiff as they congregated just below the exposed low intertidal region. Portions of some crabs were above water. Subsequent SCUBA diving revealed several hundred crabs in the low intertidal and shallow subtidal regions. All crabs appeared to have new exoskeletons. King crabs were observed feeding on green algae, polychaetous annelids, clams (*Protothaca staminea, Mya arenaria*), barnacles (*Balanus* spp.), sea urchins (*Strongylocentrotus droebachiensis*), and sea stars (*Pycnopodia helianthoides* and *Evasterias troschelii*). Small king crabs (15 mm in length) were found under rocks.

Diving was again accomplished at the Near Island Basin site in mid-May. King crabs were congregated in the shallow subtidal region only. A few crabs were observed feeding on the cockle *Clinocardium nuttallii*. Thirty-five crabs were randomly collected for stomach analysis. The crabs were mainly immature males and females, although some mature individuals of both sexes were taken.

TABLE XXIII

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA IN NEAR ISLAND BASIN May 1978. Mean Depth 5 meters

Number Examined: 35

Number Empty: 0

Percent Composition of Crab Classes[1]: 1=34.3%; 2=17.1%; 3=5.7%; 6=42.9%

Mean Length: 106±10 mm

Mean Weight: 958±315 g

Mean Percent Fullness: 4.9±7.5%

Number of Prey Taxa: 45

DOMINANT PREY

Phylum	Species[2]	% Freq. Occurrence	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	29	17.4	18.8
	Mya spp. (clam)	9	2.5	2.4
	Trochidae (snails)	14	<0.1	0.2
	Protothaca staminea (clam)	9	<0.1	0.1
Echinodermata	Echinoidea (urchins)	14	16.8	14.7
	Asteroidea (sea stars)	3	7.0	7.0
Annelida	*Owenia fusiformis* (tube-dwelling worm)	40	<0.1	0.7
	Pectinariidae (tube-dwelling worm)	23	<0.1	0.4
Arthropoda	*Balanus* spp. (barnacles)	23	0.8	5.0
Unidentified animal material		57	42.1	31.1
Unidentified plant material		66	2.7	3.9

[1] see methods for description of crab clasces

[2] species or lowest level of identification

All crabs taken in mid-May contained food. Forty-five prey taxa were identified, and the mean percent fullness was 4.9 ± 7.5%. Prey items dominating the stomach weight were molluscs, specifically *Macoma* spp. (17.4%), and echinoderms, specifically sea urchins (16.8%). Another important mollusc was the clam *Mya* sp. (2.5%). *Protothaca staminea* and gastropods of the family Trochidae each accounted for <0.1% of the total food weight. Sea stars consisted of 7% of the total food weight. Annelids (*Owenia fusiformis* and unidentified pectinarids) and barnacles (*Balanus* spp.) were frequently found among stomach contents although they contributed little to the overall stomach weight or volume.

Intestines were not examined for food content.

June 1978 (Table XXIV)

The Near Island Basin site was revisited in Mid-June. Crabs were in the same location as in May, however, unlike the aggregative behavior of crabs in May, individuals in June were mainly solitary. The crab class composition was also the same as in May. Crabs were observed feeding on the clam *Protothaca staminea*. Dense clouds of mud in deeper water resulted from crabs actively feeding in the immediate vicinity. Thirty-two king crabs were randomly collected for food analysis. All contained food.

Thirty-three prey taxa were identified and the mean percent stomach fullness was 10.6 ± 11.8%. Barnacles were the most important prey contributing 30.7% of the food weight. Unidentified pelecypods (19.1%), *Mya* sp. (12.8%), *Macoma* sp. (3.5%), and *Protothaca staminea* (0.3%) were the most important clams. Once again annelid worms were dominated by *Owenia fusiformis* and unidentified pectinarids. The latter worms were mainly composed of setae and fragments and are thought to also be *O. fusiformis*.

Food examined from the intestines of Near Island Basin king crabs was similar to food found in their stomachs.

TABLE XXIV

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA IN NEAR ISLAND BASIN June 1978. Mean Depth 6 meters

Number Examined: 32

Number Empty: 0

Percent Composition of Crab Classes[1]: 1=21.9%; 2-12.5%; 3=12.5%; 6=53.1%

Mean Length: 110±17 mm

Mean Weight: 1072±515 g

Mean Percent Fullness: 10.6±11.8

Number of Prey Taxa: 33

DOMINANT PREY

Phylum	Species[2]	% Freq. Occurrence	% by Weight	% by Volume
Mollusca	Pelecypoda (clams)	47	19.1	17.1
	Mya sp. (clam)	19	12.8	8.8
	Macoma sp. (clam)	31	3.2	3.1
	Protothaca staminea (clam)	41	0.3	2.6
Arthropoda	*Balanus* spp.[3] (barnacle)	66	30.7	20.8
Annelida	*Owenia fusiformis* (tube-dwelling worm)	50	3.1	4.1
	Pectinariidae (tube-dwelling worm)	31	0.2	1.6
Unidentified animal material		66	21.0	18.3
Sediment		66	0.5	4.0

[1] see methods for description of crab classes

[2] species or lowest level of identification

[3] includes *Balanus crenatus*

May 1979 (Table XXV)

A total of 21 king crabs were collected via SCUBA in Near Island Basin in May 1979. Most were newshell males greater than 100 mm. All but one crab was observed to be actively feeding. Food species observed in the possession of crab were a clam (*Spisula polynyma*), a seastar (*Pycnopodia helianthoides*), a mussel (*Mytilus edulis*), polychaetes and barnacles. Only one crab had an empty stomach. The mean stomach fullness among feeding crabs was 20.4 ± 15.2%. Thirty-one prey categories were identified. The dominant prey were barnacles (*Balanus crenatus*) and tube-dwelling polychaetes (*Owenia fusiformis*) which accounted for 31.2% and 18.9% of the stomach contents weight, respectively . Molluscs also were important food items, specifically the clam *Macoma* spp. (5.1% of the weight), *Protothaca staminea* (5.2%), and *Hiatella arctica* (2.6%). Unidentifiable animal and plant material were frequently found.

Food found in king crab intestines was similar to food from their stomachs.

McLinn Island (Figure 3)

May 1978 (Table XXVI)

Diving near McLinn Island in mid-May yielded 49 king crabs for stomach analysis. Crabs were not widely dispersed, but were found in aggregates of 4-8 crabs at a mean depth of 9 m. Most crabs were inactive at the time of capture. Most were immature, newshell crabs of both sexes (mean length 100 ± 9 mm). All crabs examined in the laboratory contained food (53 different prey taxa) with a mean percent fullness of 9.3 ± 11.8%. Dominant prey items were molluscs and crustaceans. The main molluscs taken were unidentified clams which contributed 30.3% of the weight. Important clams that were identified were *Hiatella arctica* (5.1%), *Macoma* spp. (1.5%), and *Protothaca staminea* (0.9%). The snail *Trichotropis cancellata* contributed 9.3% by weight. Unidentified decapods (2.7%) and *Balanus* spp. (3.3%) were the most important crustaceans.

Food examined from the intestines of McLinn Island king crabs was similar to food found in their stomachs.

TABLE XXV

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA IN NEAR ISLAND BASIN May 1979. Mean Depth 11 meters

Number Examined: 21

Number Empty: 1

Percent Composition of Crab Classes[1]: 1=4.8%; 6=95.2%

Mean Length: 125±11 mm

Mean Weight: 1571±479 g

Mean Percent Fullness[2]: 19.4±15.4%; 20.4±15.2%

Number of Prey Taxa: 31

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Balanus crenatus* (barnacles)	71	75	31.2	30.0
Annelida	*Owenia fusiformis* (tube-dwelling worm)	62	65	18.9	22.7
Mollusca	*Macoma* spp. (clams)	52	55	5.1	5.1
	Protothaca staminea (clams)	43	45	5.2	5.4
	Hiatella arctica (clams)	33	35	2.6	2.7
Unidentified animal material		95	100	18.3	18.8
Unidentified plant material		81	85	3.4	2.7

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XXVI

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA NEAR McLINN ISLAND May 1978. Mean Depth 9 meters

Number Examined: 49

Number Empty: 0

Percent Composition of Crab Classes[1]: 1=42.9%; 2=22.4%; 3=18.4%; 6=16.3%

Mean Length: 100±9 mm

Mean Weight: 758±183 g

Mean Percent Fullness: 9.3±11.8%

Number of Prey Taxa: 53

DOMINANT PREY

Phylum	Species[2]	% Freq. Occurrence	% by Weight	% by Volume
Mollusca	Pelecypoda (clams)	49	30.3	31.4
	Trichotropis cancellata (snail)	31	9.3	7.2
	Hiatella arctica (clam)	43	5.1	4.2
	Macoma sp. (clam)	41	1.5	1.3
	Protothaca staminea (clam)	18	0.9	0.8
Arthropoda	Decapoda	39	2.7	1.5
	Balanus spp.[3] (barnacles)	29	3.3	2.7
Unidentified animal material		75	16.8	16.6
Unidentified plant material		73	3.3	3.9
Unidentified material		55	16.1	16.7

[1] see methods for description of crab classes

[2] species or lowest level of identification

[3] includes *Balanus crenatus*

BEST DOCUMENT AVAILABLE

An attempt was made to locate king crabs *via* SCUBA in the shallows of nearby Kalsin Bay and Womans Bay in mid-May. No crabs were found although they were reported one week earlier by ADF&G divers.

The McLinn Island site was revisited in mid-June and no crabs were found.

May 1979 (Table XXVII)

The 16 king crabs collected near McLinn Island in May 1979 came from a location approximately 450 m northwest of the McLinn Island site of May 1978. Most crabs were new, softshell gravid females. Only eight out of 16 crabs contained food. The eight empty stomachs were all from softshell females. The mean stomach fullness of the 16 crabs was 2.7 ± 4.1%; the fullness among feeding crabs was 5.4 ± 4.4%. Twenty-one prey taxa were identified. Dominant prey species were the snow crab (*Chionoecetes bairdi*) and barnacles (*Balanus crenatus*) which comprised 34.6% and 6.7% of the stomach contents biomass, respectively. Other important prey included the bivalve molluscs, *Macoma* spp., *Protothaca staminea* and *Clinocardium* spp. which accounted for 3.7%, 0.9%, and 0.9% of the food weight, respectively. Unidentified animal and plant material made up 26.7% and 3.0% of the weight, respectively.

Food examined from the intestines of McLinn Island king crabs was similar to food found in their stomachs.

Anton Larsen Bay - Site 1 (Figure 3)

June 1978 (Table XXVIII)

Two sites were examined by SCUBA in Anton Larsen Bay to obtain king crabs. One collection (site 1) was made across the bay from the public boat ramp. The dive began on a steep slope at 19 m. While ascending up the slope toward shore it was apparent that barnacles had recently been removed from the rocky substrate. King crabs were observed at 9 m depth as single individuals or groups of 2-4. All appeared to be actively feeding . Thirty-one crabs were collected, of which 9.4% were newshell

TABLE XXVII

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA NEAR McLINN ISLAND
May 1979. Mean Depth 15 meters

Number Examined: 16

Number Empty: 8

Percent Composition of Crab Classes[1]: 1=6.3%; 2=81.3%; 6=12.5%

Mean Length: 116±35 mm

Mean Weight: 1087±539 g

Mean Percent Fullness[2]: 2.7±4.1%; 5.4±4.4%

Number of Prey Taxa: 21

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Chionoecetes bairdi* (crab)	19	37	34.6	32.1
	Balanus crenatus (barnacle)	19	37	6.7	6.6
Mollusca	*Macoma* spp. (clam)	6	12	3.7	3.5
	Protothaca staminea (clam)	6	12	0.9	0.9
	Clinocardium spp. (cockle)	6	12	0.9	0.9
Unidentified animal material		50	100	26.7	27.5
Unidentified plant material		19	37	3.0	2.8

[1] see methods for description of crab classes

[2] based on all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XXVIII

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA AT ANTON LARSEN BAY (Site #1) June 1978. Mean Depth 9 meters

Number Examined: 31

Number Empty: 4

Percent Composition of Crab Classes[1]: 1=6.3%; 2=9.4%; 6=3.1%; 7=81.3%

Mean Length: 118±13 mm

Mean Weight: 1356±472 g

Mean Percent Fullness[2]: 4.1±4.9%; 4.7±4.9%

Number of Prey Taxa: 25

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Balanus* spp. (barnacles)	39	44	46.1	34.8
	Balanus crenatus (barnacle)	10	11	11.2	7.5
Mollusca	*Macoma* spp. (clam)	16	19	4.4	5.9
	Gastropoda (snail)	10	11	1.6	2.3
	Protothaca staminea (clam)	10	11	0.5	0.4
	Clinocardium spp. (cockle)	3	4	0.9	1.1
Cnidaria	Hydrozoa (hydroid)	52	59	0.2	1.1
Annelida	*Owenia fusiformis* (tube-dwelling worm)	16	19	0.3	0.7
Unidentified plant material		68	78	11.5	14.3
Unidentified animal material		32	37	5.0	7.1
Sediment		32	37	<0.1	0.7

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

ovigerous females and 81.3% were oldshell males greater than 100 mm. Only four of the crabs examined in the laboratory did not contain food. The mean percent fullness of crabs with food was 4.7 ± 4.9%. Stomach contents were dominated by barnacles which made up 57.3% of the stomach weight. Molluscs, specifically *Macoma* spp. (4.4%), gastropods (1.6%), *Protothaca staminea* (0.5%), and *Clinocardium* spp. (0.9%) were also important. Hydroids were frequently taken (52% of the total stomachs examined) but yielded only 0.2% of the volume.

Food examined from the intestines of Anton Larsen Bay site 1 king crabs was similar to food found in their stomachs.

Anton Larsen Bay - Site 2 (Figure 3)

June 1978 (Table XXIX)

The second June 1978 collection of king crabs in Anton Larsen Bay was in a rocky, kelp-covered region approximately 1.8 km west of the boat ramp. A few crabs were observed feeding on barnacles. Approximately 12 large and very oldshell male king crabs were found dead and decaying in this region. Twenty-one crabs were collected at an average depth of 9 m; 43% were newshell ovigerous females and 48% were oldshell males of mixed maturity. All crabs examined in the laboratory, except one, contained food. Food was similar to that found in the crabs at site 1. Barnacles, mainly *Balanus crenatus*, accounted for 75% of the total prey weight. Major molluscs consisted of unidentified clams (1.6%), *Protothaca staminea* (1.4%), *Hiatella arctica* (0.3%), and *Macoma* spp. (1.0%). Hydroids were found in 76% of the crabs examined, but accounted for only 0.2% of the weight.

Food examined from the intestines of king crabs from Anton Larsen Bay site 2 was similar to food found in their stomachs.

Anton Larsen Bay - Site 2 (Figure 3)

May 1979 (Table XXX)

Diving in Anton Larsen Bay (site 2) in May 1979 yielded 17 king crabs for stomach analysis. Newshell adult males and females dominated the catch.

TABLE XXIX

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA AT ANTON LARSEN BAY (Site #2) June 1978. Mean Depth 9 meters

Number Examined: 21

Number Empty: 1

Percent Composition of Crab Classes[1]: 1=9%; 2=43%; 7=48%

Mean Length: 122±19 mm

Mean Weight: 1376±771 g

Mean Percent Fullness[2]: 11.5±13.9%; 12±14%

Number of Prey Taxa: 32

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Balanus crenatus* (barnacles)	52	55	69.5	63.5
	Balanus spp. (barnacles)	33	35	5.2	5.1
Mollusca	Pelecypoda (clams)	38	40	1.6	1.8
	Protothaca staminea (clam)	24	25	1.4	1.5
	Hiatella arctica (clam)	33	35	0.3	0.6
	Macoma spp. (clam)	14	15	1.0	0.8
Cnidaria	Hydrozoa (hydroid)	76	80	0.2	0.8
Unidentified plant material		76	80	8.2	10.6

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XXX

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* SCUBA IN ANTON LARSEN BAY (Site #2) May 1979. Mean Depth 6 meters

Number Examined: 17

Number Empty: 0

Percent Composition of Crab Classes[1]: 2=64.7%; 6=29.4%; 7=5.9%

Mean Length: 121±15 mm

Mean Weight: 1388±648 g

Mean Percent Fullness: 8±12.3%

Number of Prey Taxa: 31

DOMINANT PREY

Phylum	Species[2]	% Freq. Occurrence	% by Weight	% by Volume
Mollusca	*Hiatella arctica* (clam)	41	3.7	3.9
	Clinocardium spp. (cockle)	24	9.7	9.6
	Serripes groenlandicus (cockle)	12	11.1	10.8
Arthropoda	*Balanus crenatus* (barnacle)	65	16.6	15.8
Unidentified animal material		100	38.4	39.6
Unidentified plant material		82	2.9	2.4

[1] see methods for description of crab classes

[2] species or lowest level of identification

All crab contained food and had a mean stomach fullness of 8 ± 12.3%. Thirty-one prey taxa were identified, and bivalves and barnacles were the dominant prey. The bivalves *Hiatella arctica*, *Clinocardium* spp., and *Serripes groenlandicus* were most important yielding 3.7%, 9.7%, and 11.1% of the food biomass, respectively. The barnacle *Balanus crenatus* occurred in 65% of the crab and accounted for 16.6% of the food biomass. Unidentified animal and plant material were frequently found and made up 38.4% and 2.9% of the food biomass, respectively.

Food examined from the intestines of king crabs from Anton Larsen Bay site 2 was similar to food found in their stomachs.

Kodiak Shelf (Figure 5)

June-July 1978 (Tables XXXI, XXXII)

The June-July cruise on the Kodiak Shelf yielded 196 king crab stomachs from nine stations. One hundred and eighty-seven crabs (95%) had food in their stomachs. The crabs were mainly composed of newshell ovigerous females (42.9%) and newshell males greater than 100 mm in carapace length (42.3%). The mean percent fullness for crabs containing food was 9.5 ± 10.1%. Although Station 14 had the highest mean percent stomach fullness, 21.4 ± 18.2%, only four crabs were collected and examined. Crabs of Stations 13 and 9 also had high stomach fullnesses, 16.2 ± 26.7% and 13.5 ± 9.1%, respectively. King crabs from Station 9 had the highest diversity of prey taxa (73) and the highest diversity of prey taxa within a single crab (25). The fullest king crab stomach was 78.1% full; a 112 mm ovigerous female from Station 13. This crab was feeding on *Chionoecetes bairdi* and fish.

Ninety-eight different prey taxa were identified from crabs taken at all stations. Dominant prey belonged to three phyla: Mollusca, Arthropoda and Chordata. Clams were the most important molluscs. The clams *Nuculana* spp. and *Nucula tenuis* made up 23.4% and 8.4% of the weight, respectively, and were important prey at Stations 7, 8, 9 and 10. Important arthropods were unidentified decapods (6.0%), *Chionoecetes bairdi* (4.5%), and the pea crab *Pinnixa occidentalis* (9.4%). The decapods

TABLE XXXI

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS ON THE KODIAK SHELF June-July 1978. Mean Depth 118±44 meters

Number Examined: 196

Number Empty: 9

Percent Composition of Crab Classes[1]: 1=5.6%; 2=42.9%; 3=2%; 6=42.3%; 7=6.1%; 8=1%

Mean Length: 119±18 mm

Mean Weight: 1379±669 g

Mean Percent Fullness[2]: 9.1±10%; 9.5±10.1

Number of Prey Taxa: 98

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Nuculana* spp. (clams)	63	60	23.4	21.0
	Nucula tenuis (clam)	56	58	8.4	7.1
	Pandora grandis (clam)	20	21	2.7	2.2
	Axinopsida serricata (clam)	40	42	0.6	0.8
	Clinocardium spp. (cockle)	26	27	<0.7	0.7
Arthropoda	Decapoda	27	28	6.0	6.4
	Chionoecestes bairdi (snow crab)	26	27	4.5	4.5
	Pinnixa occidentalis (pea crab)	11	11	9.4	9.7
Chordata	Pisces (fishes)	29	30	19.6	20.7
Unidentified animal material		60	63	10.4	10.3

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XXXII

STATION DATA AND STOMACH CONTENTS OF KING CRABS COLLECTED VIA TRAWLS ON THE KODIAK SHELF
June-July 1978

Station Name	1	7	8	9
$\bar{X}$ Depth, m	68	55	73	140
Number Examined	7	33	40	44
Number Empty	0	6	0	0
% Crab composition[1]	2=100%	1=18%, 2=39%; 3=3%; 6=40%	1=5%; 2=45%; 3=5%; 6=35%; 7=10%	1=2%; 2=43%; 6=50%; 7=4%
$\bar{X}$% Fullness[2]	5.6±7.1%	4.5±5.8%	5.3±6.5%	13.5±9.1%
Prey taxa	17	25	30	73
Dominant prey-% wt.	Pelecypoda-43.7 Unid. Animal-21.4 *Ophiura sarsi*-21.3 Ophiuridae-8.8	Decapoda-37.1 *Nucula tenuis*-21.2 *Nuculana fossa*-20.7 Unid. Plant-12.4 *Axinopsida serricata*-3.4	Pisces-32.2 *Nucula tenuis*-16.6 *Nuculana fossa*-9.3 Decapoda-8.1 *Yoldia* spp.-6.9 *Macoma* spp.-1.7 *Clinocardium* sp.-0.2 *Axinopsida serricata*-<0.1	*Nuculana* spp.-61.4 *Nucula tenuis*-13.9 *Pandora grandis*-9.0 Unid. animal-3.8 *Chionoecetes bairdi*-3.6 *Axinopsida serricata*-0.5

Station Name	10	11	12	13
$\bar{X}$ Depth, m	126	117	135	173
Number examined	16	16	28	8
Number empty	1	1	1	0
% Crab composition[1]	2=38%; 6=44%; 7=6%; 8=12%	1=6%; 2=44%; 3=6%; 6=31%; 7=12%	1=4%; 2=36%; 6=53%; 7=7%	2=37%; 6=50%; 7=13%
$\bar{X}$% Fullness[2]	8.3±10.6%	6.8±6.0%	11.7±6.8%	16.7±26.7%
Prey taxa	39	16	31	11
Dominant prey-% wt.	Pisces-40.7 Unid. animal-20.2 *Nuculana fossa*-13.4 *Nucula tenuis*-4.8 *Chionoecetes bairdi*-4.1 Decapoda-4.1 *Axinopsida serricata*-1.0	Unid. animal-46.9 Pisces-30.0 Pandalidae-12.7 Decapoda-5.3 *Paralithodes camtschatica*-3.8 *Axinopsida serricata*-<0.1	*Pinnixa occidentalis*-47.3 Pisces-23.0 Unid. animal-17.8 Decapoda-3.2 *Macoma* spp.-1.3 *Axinopsida serricata*-0.4	Pisces-46.9 *Chionoecetes bairdi*-31.0 Unid. plant-17.3

Station Name	14
$\bar{X}$ Depth, m	176
Number examined	4
Number empty	0
% Crab composition[1]	2=25%; 6=75%
$\bar{X}$% Fullness[2]	21.4±18.2%
Prey taxa	12
Dominant prey-% wt.	Pisces-55.6 Decapoda-4.3 Unid. plant-4.2 *Nuculana fossa*-4.1 *Chionoecetes bairdi*-3.1

---

[1] see methods for description of crab classes

[2] based on all stomachs examined

were important prey at Stations 7, 8, 11, 12 and 14. *Chionoecetes bairdi* was important prey at Stations 9, 13 and 14, and *Pinnixa occidentalis* was important at Station 12. Fishes accounted for 19.6% of the weight and were found in 29% of the crabs. Fishes were important prey at Stations 8, 10, 11, 12, 13 and 14. Unidentified animal material made up 10.4%.

Food found in king crab intestines were similar to food found in their stomachs.

February 1979 (Tables XXXIII, XXXIV)

King crabs examined in stomach analysis in February 1979 came from Stations 7, 8 and 23. Seventeen out of 22 crab had food in their stomachs. Only males, mainly oldshell males, were examined. The mean percent fullness among feeding crabs was 1.7 ± 3.4%. Most of the food contents were composed of unidentified animal material (62.8% by weight), although 14 other food categories were identified. Fishes comprised 9.9% by weight and occurred in 23% of the crab examined. Fishes were a most important food at Stations 7 and 8. Hermit crabs (Paguridae) made up 9% of the weight of stomach contents and occurred in 9% of the crab examined. Molluscs, specifically protobranch clams, *Nuculana* spp., were important food items at all three stations, although *Nuculana* spp. only contributed 2.7% by weight of the stomach contents.

Food found in king crab intestines were similar to food found in their stomachs.

Statistical Analysis - King Crab

In order to determine how well king crab stomach weight and volume (fullness) were correlated, the spearman rank correlation (Zar, 1974) was used on feeding crabs. The correlation coefficient was 0.89 with a P value of 0.001, showing that stomach weight and volume were strongly related. Since either weight or volume could be used in the statistical analyses, we decided to use food weight.

King crab food

Food items taken by king crabs were categorized into nine groups, i.e., plant material, Annelida (Polychaeta), Mollusca, Arthropoda (Crustacea),

TABLE XXXIII

STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS ON THE KODIAK SHELF
February 1979. Mean Depth 60±8.9 meters

Number Examined: 22

Number Empty: 5

Percent Composition of Crab Classes[1]: 6=13.6%; 7=86.4%

Mean Length: 150±19 mm

Mean Weight: 2745±928 g

Mean Percent Fullness[2]: 1.3±3.1%; 1.7±3.4%

Number of Prey Taxa: 15

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Mollusca	*Nuculana* spp. (clams)	23	29	2.7	2.8
	Polinices spp. (gastropod)	5	6	3.8	3.9
Chordata	Pisces (fishes)	23	29	9.9	10.6
Arthropoda	Paguridae (hermit crabs)	9	12	9.0	9.2
Sediment		55	71	1.3	1.2
Unidentified animal material		68	88	62.8	62.1

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

[3] species or lowest level of identification

TABLE XXXIV

STATION DATA AND STOMACH CONTENTS OF KING CRABS COLLECTED *VIA* TRAWLS ON THE KODIAK SHELF, FEBRUARY 1979

Station Name	7	8	23
$\bar{x}$ Depth, m	53	70	57
Number Examined	10	4	8
Number Empty	1	0	4
% Crab Composition[1]	6=10%; 7=90%	6=25%; 7=75%	6=12.5%; 7=87.5%
$\bar{x}$% Fullness[2]	0.9±0.8% 0.8±0.8%	3.4±6.7%	1.8±3.1% 0.9±2.2%
Prey Taxa	10	8	11
Dominant Prey-% Wt.	Unid. animals-59.1 Pisces-34.4	Unid. animal-64.9 Paguridae-14.9 Shrimp-14.9	Unid. animal-63.1 Paguridae-9.0 *Polinices*-9.0 *Nuculana* spp.-6.5

---

[1] see methods for description of crab classes

[2] based on: all stomachs examined; all stomachs with food

TABLE XXXV

DATA EMPLOYED IN THE WILCOXON RANK SUM TEST FOR CONSIDERATION OF DIFFERENCE BETWEEN AMOUNT OF FOOD CONSUMED BETWEEN SEXES OF KING CRAB. Values are median food weights

Food Group	Male	Female
Plant	0.001	0.001
Annelida	0.001	0.001
Mollusca	0.010	0.005
Arthropoda	0.030	0.010
Echinodermata	0.001	0.001
Pisces	0.110	0.250

Echinodermata, Pisces, unidentified animal material, unidentified material and sediment. With the use of the median weight of six identifiable food groups the Wilcoxon Rank Sum Test (Zar, 1974) was employed to test the null hypothesis that there is no difference in amount of food consumed between sexes. The test revealed no significant difference (P = 0.469) in food consumed by males and females (Table XXXV).

When both sexes were combined, molluscs and crustaceans were the dominant food groups, in terms of percent wet weight and frequency of occurence (Table XXXVI). Pisces was the next most important group, in terms of weight, although, it was least frequently consumed.

The mean amount of prey consumed by feeding crabs was 1.41 g/crab or 0.001 g of prey/g of predator.

King crab food *versus* crab size

King crab that were examined in this study were divided into seven size categories, most of which were in 20 mm increments. Most crabs belonged to the 100-119 mm (52%) and 120-139 mm (24%) size groups. Numerical differences in gravimetric percentages of major food categories among size groups were small. The Friedman Analysis of Variance Test (Zar, 1974) was employed to test each of the major food categories among size groups. No significant differences were revealed at $\alpha = 0.05$ (Table XXXVII).

When the Kruskal-Wallis Test (Zar, 1974) was employed on the weight of food consumed by crabs of various size groups, significant differences were detected in both feeding crabs and all crabs, including those with empty stomachs (Table XXXVIII). The different pairs among feeding crabs were 80-99 mm < 120-139 mm and 120-139 mm > 160-179 mm, and the different pairs among all crabs were 80-89 < 120-139 mm, 100-119 mm > 160-179 mm, 120-139 mm > 160-179 mm, and 120-139 > 180-187 mm, as determined by Dunn's Technique (Dunn, 1964).

When the percentage of stomach fullness was compared by various size groups, it was revealed that many pairs were significantly different among both feeding crabs and all crabs. Furthermore, king crabs < 140 mm had fuller stomach than crabs 140 mm or greater (Table XXXIX).

King crab food *versus* crab class

The majority of the crabs examined consisted of two crab classes; new-shell ovigerous females greater than 95 mm in length (Class 2) (37%) and

TABLE XXXVI

SUMMARY OF THE STOMACH CONTENTS OF *PARALITHODES CAMTSCHATICA* FOR 809 CRABS EXAMINED

Food category	Food wet weight Total (g)	Food wet weight Percent	Percent frequency of occurrence
Mollusca	322.78	32.5	69.2
Crustacea	311.88	31.4	52.0
Pisces	126.51	12.7	15.3
Plant	28.79	2.9	30.7
Echinodermata	28.00	2.8	16.3
Annelida	25.12	2.5	35.6
Unid. animal material	134.31	13.5	46.5
Unid. material	13.12	1.3	23.5
Sediment	3.74	0.4	29.7
Total wet weight	994.15	100.0	

TABLE XXXVII

SUMMARY OF STOMACH CONTENTS OF 809 *PARALITHODES CAMTSCHATICA* BY SIZE GROUPS

(A) Total wet weight (g) of each food category; (B) gravimetric percent of each food category; and (C) percent frequency of occurrence

Size group	I			II			III		
Carapace length, mm	60-79			80-99			100-119		
Sample size	7			94			423		
Food category	A	B	C	A	B	C	A	B	C
Mollusca	1.22	35.9	86	24.14	56.8	82	173.16	38.6	70
Crustacea	2.16	63.5	71	9.63	22.7	55	194.21	43.3	55
Pisces	0	0	0	5.41	12.7	10	51.70	11.5	15
Plant	<0.01	0.3	14	1.71	4.0	43	9.58	2.1	30
Annelida	<0.01	0.3	14	1.55	3.6	15	6.82	1.5	37
Echinodermata	0	0	0	0.05	0.1	17	13.02	2.9	19

Size group	IV			V			VI			VII		
Carapace length, mm	120-139			140-159			160-179			180-200		
Sample size	193			71			16			5		
Food category	A	B	C	A	B	C	A	B	C	A	B	C
Mollusca	94.49	37.2	64	23.99	27.8	52	4.99	70.4	56	0.68	58.6	20
Crustacea	87.62	34.5	55	16.34	18.9	37	1.52	21.4	19	0.40	34.5	20
Pisces	36.43	14.3	18	32.58	37.8	20	0.34	4.8	19	0.04	3.4	20
Plant	16.28	6.4	35	0.99	1.1	15	0.22	3.1	12	0	0	0
Annelida	16.15	6.4	31	0.54	0.6	20	0.01	0.1	12	0.04	3.4	20
Echinodermata	3.09	1.2	12	11.85	13.7	17	<0.01	0.1	6	0	0	0

TABLE XXXVIII

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR KING CRAB FOOD WEIGHT AND CRAB SIZE GROUPS

Size (mm)	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
65- 79	7	2335.0	7	1661.0
80- 99	94	34285.0	87	25580.0
100-119	423	175459.0	383	136672.0
120-139	193	83097.5	162	66164.0
140-159	71	27281.5	60	20970.5
160-179	16	4225.0	13	2823.0
180-187	5	962.0	1	670.0

Pairs significantly different ($P<0.05$)

Stomachs examined	Stomachs w/food
80- 99 < 120-139	
100-119 > 160-179	80- 99 < 120-139
120-139 > 160-179	120-139 > 160-179
120-139 > 180-187	

---

[1] critical Kruskal-Wallis test statistic = 17.04
calculated P-value = 0.009 assuming a χ^2 distribution with 6 d.f.

[2] critical Kruskal-Wallis test statistic = 28.98
calculated P-value ≈ 0 assuming a χ^2 distribution with 6 d.f.

TABLE XXXIX

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR KING CRAB STOMACH FULLNESS (%) AND CRAB SIZE GROUPS

Size (mm)	Stomachs examined	Rank sum[1] of fullness	Stomachs w/food	Rank sum[2] of fullness
65- 79	7	2932.5	7	2253.5
80- 99	94	40319.5	87	31668.0
100-119	423	182897.0	383	144306.5
120-139	193	76144.0	162	58977.5
140-159	71	21837.0	60	15508.5
160-179	16	2805.5	13	1409.0
180-187	5	709.0	1	418.0

Pairs significantly different ($P<0.05$)

Stomachs examined	Stomachs w/food
	80- 99 > 140-159
80- 99 > 140-159	80- 99 > 160-179
80- 99 > 160-179	100-119 > 140-159
100-119 > 140-159	100-119 > 160-179
100-119 > 160-179	120-139 > 140-159
120-139 > 160-179	120-139 > 160-179

---

[1] critical Kruskal-Wallis test statistic = 41.41
calculated P-value ≈ 0 assuming a χ^2 distribution with 6 d.f.

[2] critical Kruskal-Wallis test statistic = 36.78
calculated P-value ≈ 0 assuming a χ^2 distribution with 6 d.f.

newshell males greater than 100 mm (Class 6) (30%). Oldshell males greater than 100 mm (Class 7) and newshell juvenile females less than 120 mm (Class 1) accounted for 17 and 11% of the crabs, respectively. Newshell and oldshell males less than 100 mm (Class 3 and 4, respectively) and very oldshell males greater than 100 mm (Class 8) collectively made up less than five percent of all crabs examined. No very oldshell males less than 100 mm (Class 5) occurred.

The Kruskal-Wallis Test revealed significant differences in amount of food consumed among the seven king crab classes in both feeding crabs and all crabs (Table XL). Among all crabs examined, class 6 crabs consumed significantly more food than class 8 crabs. Among only feeding predators, class 1 consumed significantly less food than classes 2 and 6.

King crab food *versus* sampling period

The effect of sampling periods on the amount of food consumed by two categories of king crabs (crabs containing food and all crabs, including those with empty stomachs) was examined. In both crab categories, the Kruskal-Wallis Test revealed a significant difference in the amount of food consumed between months, i.e., food consumed in at least one of the months was different from the other months (Table XLI).

When examining the monthly differences in the amount of food in all crabs, including those with empty stomachs, it was found that many months were different. The majority of these differences were between crabs of spring-summer months (May, June and July) *versus* fall-winter months (August, November and February). However, crabs examined in April 1978 were mainly empty and were therefore different from crabs of most other sampling periods, including spring and summer months.

Differences in quantity of food among feeding crabs was detected between ten month *versus* month cases. Among these cases, eight were between spring-summer months *versus* fall-winter months.

King crab food *versus* sampling area

When weight of food from all king crabs was analyzed from all six sampling sites the Kruskal-Wallis Test revealed a significant difference in amount of food consumed between sampling areas (Table XLII). Significant pairs were Near Island Basin > Kiliuda Bay, and McLinn Island and Kiliuda Bay < the Kodiak Shelf.

TABLE XL

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR KING CRAB FOOD WEIGHT AND CRAB CLASSES.

Crab[1] Class	Stomachs Examined	Rank Sum[2] of contents	Stomachs w/food	Rank Sum[3] of contents
1	87	33047.0	84	24812.0
2	297	116051.0	246	89891.5
3	24	9645.0	23	7384.0
4	5	2483.5	5	2003.5
6	245	108696.5	225	86082.5
7	141	55277.9	124	42697.0
8	10	2445.0	6	1670.0

Pairs significantly different ($P<0.05$)	
Stomachs examined	Stomachs w/food
class 6 > class 8	class 1 < class 2
	class 1 < class 6

---

[1] see methods for description of crab class

[2] critical Kruskal-Wallis test statistic = 14.77
calculated P-value = 0.0221 assuming a χ^2 distribution with 6 d.f.

[3] critical Kruskal-Wallis test statistic = 13.67
calculated P-value = 0.0335 assuming a χ^2 distribution with 6 d.f.

TABLE XLI

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR KING CRAB FOOD WEIGHT AND SAMPLING PERIOD

Sampling period	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
Apr. 1978	47	6727.5	15	3715.5
May 1978	84	32197.0	84	24121.0
Jun. 1978	194	83366.5	182	65436.5
Jul. 1978	272	132357.0	261	106743.0
Aug. 1978	43	10278.5	30	6753.0
Nov. 1978	55	19548.5	49	14535.5
Feb. 1979	22	5209.5	17	3323.5
Mar. 1979	38	13136.5	30	9855.5
May 1979	54	24824.0	45	20057.5

Pairs significantly different ($P<0.05$)

Stomachs examined

Apr. 1978 < May 1978
Apr. 1978 < Jun. 1978
Apr. 1978 < Jul. 1978
Apr. 1978 < Nov. 1978
Apr. 1978 < Mar. 1979
Apr. 1978 < May 1979
May 1978 < Jul. 1978
Jun. 1978 > Aug. 1978
Jun. 1978 > Feb. 1978
Jul. 1978 > Aug. 1978
Jul. 1978 > Nov. 1978
Jul. 1978 > Feb. 1979
Jul. 1978 > Mar. 1979
Aug. 1978 < May 1979
Feb. 1979 < Aug. 1979

Stomachs w/food

May 1978 < Jul. 1978
May 1978 < May 1979
Jun. 1978 > Aug. 1978
Jun. 1978 > Feb. 1978
Jul. 1978 > Aug. 1978
Jul. 1978 > Nov. 1978
Jul. 1978 > Feb. 1979
Aug. 1978 < May 1979
Nov. 1978 < May 1979
Feb. 1978 < May 1979

---

[1] critical Kruskal-Wallis test statistic = 136.30
calculated P-value $\approx$ 0 assuming a χ^2 distribution with 8 d.f.

[2] critical Kruskal-Wallis test statistic = 66.43
calculated P-value $\approx$ 0 assuming a χ^2 distribution with 8 d.f.

TABLE XLII

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR KING CRAB FOOD WEIGHT AND SAMPLING AREA

Sample area	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
Near Island Basin	88	40701.5	87	32305.0
McLinn Island	65	23824.0	57	17964.0
Anton Larsen Bay	69	29933.0	64	23546.5
Kiliuda Bay	329	115075.0	264	86578.5
Izhut Bay	40	17376.5	37	13678.5
Kodiak Shelf	218	100735.5	204	80472.5

Pairs significantly different (P<0.05)	
Stomachs examined	Stomachs w/food
Near Island Basin > Kiliuda Bay	McLinn Island < Kodiak Shelf
McLinn Island < Kodiak Shelf	Kiliuda Bay < Kodiak Shelf
Kiliuda Bay < Kodiak Shelf	

---

[1] critical Kruskal-Wallis test statistic = 40.23
calculated P-value ~ 0 assuming a χ^2 distribution with 5 d.f.

[2] critical Kruskal-Wallis test statistic = 15.09
calculated P-value = 0.0100 assuming a χ^2 distribution with 5 d.f.

When crabs with food in their stomachs were compared by areas a significant difference in food weight was detected. Crabs from the Kodiak Shelf consumed significantly more food than crabs from McLinn Island and Kiliuda Bay.

King crab food *versus* depth

Depths at which king crabs were collected were divided into eight groups; 0-25 m, 26-50, 51-75, 76-100, 101-125, 126-150, 151-175 and 176-200 m.

The Kruskal-Wallis Test revealed that the quantity of food consumed by all crabs and feeding crabs at the eight different depth strata was significantly different (Table XLIII). Many different pairs were detected among all crabs examined.

Upon examining feeding crabs by depth intervals we found that the amount of food consumed at most depths was similar, however, the depth 126-150 m was an exception. Because of the preponderance of food in their stomachs, crabs at the latter depth were different from crabs at all other strata. King crabs taken from 126-150 m came from Stations 9, 10, and 12 on the Kodiak Shelf during the June-July 1978 sampling.

Chionoecetes bairdi (Snow Crab)

A total of 1025 snow crabs > 40 mm (carapace width) and 475 crabs ≤ 40 mm were examined for food contents in the present study (Tables XLIV and XLV). A total of 857 crabs > 40 mm and 456 ≤ 40 mm contained food. Stomach contents of snow crabs ≤ 40 mm are listed in Appendix B - Table II. Most crabs came from stations in Izhut Bay, Kiliuda Bay, and the outer Kodiak Shelf. All crabs were obtained during 11 different sampling periods.

Izhut Bay (Figure 1)

April 1978 (Table XLVI)

Snow crabs > 40 mm were examined for stomach contents from Stations 501 and 554. Among the 18 crabs examined 14 (78%) were males. All crabs examined had newshell exoskeletons. The mean carapace width was 75.7 ± 22.8 mm.

Nine prey taxa were identified among the stomach contents of 16 feeding crabs. Polychaetous annelids, which occurred in 83% of the crabs

TABLE XLIII

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR KING CRAB FOOD WEIGHT AND DEPTH.

Depth m	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
0- 25	284	118291.0	255	92361.0
26- 50	63	18358.0	44	13190.5
51- 75	178	71800.5	164	55503.5
76-100	128	38433.5	100	27428.5
101-125	16	7322.0	15	5830.0
126-150	88	49537.0	86	41177.5
151-175	8	3977.0	8	3209.0
176-200	44	19926.0	41	15841.0

Pairs significantly different ($P<0.05$)

Stomachs examined	Stomachs w/food
0- 25 > 26- 50	0- 25 > 76-100
0- 25 > 76-100	0- 25 < 126-150
0- 25 < 126-150	26- 50 < 126-150
26- 50 < 51- 75	51- 75 < 126-150
26- 50 < 126-150	76-100 < 126-150
26- 50 < 176-200	
51- 75 > 76-100	
51- 75 < 126-150	
76-100 < 126-150	
76-100 < 176-200	

---

[1] critical Kruskal-Wallis test statistic = 85.54 calculated P-value ≈ 0 assuming a χ^2 distribution with 7 d.f.

[2] critical Kruskal-Wallis test statistic = 52.66 calculated P-value ≈ 0 assuming a χ^2 distribution with 7 d.f.

TABLE XLIV

NUMBERS AND LOCATIONS OF SNOW CRABS (>40 mm) EXAMINED FOR FOOD CONTENTS

	Izhut Bay Stations																				
	2	3	4	6	7	8	9	501	526	527	551	554	557	582	584	585	676	677	678	679	Totals
April 1978	-	-	-	-	-	-	-	1	-	-	-	17	-	-	-	-	-	-	-	-	18
May 1978	20	20	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	45
June 1978	-	20	-	-	19	40	-	-	-	-	-	21	-	1	-	-	-	-	-	-	101
July 1978	-	22	16	-	-	20	13	-	3	2	-	17	6	-	1	1	-	-	-	-	101
August 1978	-	-	-	11	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31
November 1978	-	-	-	-	20	-	-	-	-	2	-	-	23	-	-	-	-	-	-	-	45
March 1979	-	-	-	-	-	-	-	-	-	-	4	7	14	-	-	-	8	4	19	20	76
TOTALS	20	62	16	11	39	80	13	1	3	4	4	62	48	1	1	1	8	4	19	20	417

	Kiliuda Bay Stations												
	5	6	7	501	576	577	579	580	676	677	678	SHR	Totals
April 1978	-	-	-	-	1	-	1	6	-	-	-	2	10
June 1978	-	-	-	-	-	-	2	4	-	-	-	13	19
July 1978	-	21	-	2	1	-	-	-	-	-	-	7	31
August 1978	-	-	-	1	-	-	3	3	-	-	-	8	15
November 1978	11	-	18	-	-	-	1	1	-	-	-	5	36
March 1979	-	-	-	5	-	8	1	-	4	10	3	-	31
TOTALS	11	21	18	8	2	8	8	14	4	10	3	35	142

	Kodiak Shelf Stations					
	2	8	10	20	26	Total
March 1978	20	20	20	18	10	88

	Kodiak Shelf Stations													
	4	7	8	9	10	11	12	13	14	23	44	53	55	Totals
June-July 1978	15	20	20	16	16	20	20	20	20	-	-	-	-	167
February 1979	20	20	20	-	20	20	20	-	20	19	20	12	20	211
TOTALS	35	40	40	16	36	40	40	20	40	19	20	12	20	378

TABLE XLV

NUMBERS AND LOCATIONS OF SNOW CRABS (≤40 mm) EXAMINED FOR FOOD CONTENTS

	Izhut Bay Stations													
	3	4	501	526	527	551	552	553	554	557	580	582	584	Totals
April 1978	–	–	2	–	3	–	2	–	6	–	–	–	–	13
May 1978	–	–	–	13	14	–	–	–	–	45	–	–	–	72
June 1978	–	–	–	30	–	–	–	–	7	–	–	21	–	58
July 1978	1	4	–	9	–	–	–	–	–	–	3	–	3	20
November 1978	–	–	–	–	9	–	–	7	–	1	–	–	–	17
March 1979	–	–	–	–	–	1	–	–	–	14	–	5	–	20
TOTALS	1	4	2	52	26	1	2	7	13	60	3	26	3	200

	Kiliuda Bay Stations								
	5	501	576	577	578	579	580	SHR	Totals
April 1978	–	–	1	8	1	12	30	2	54
June 1978	–	–	19	–	–	38	38	3	98
July 1978	–	18	–	–	1	–	–	1	20
August 1978	–	6	–	–	–	8	6	–	20
November 1978	2	–	7	–	–	2	3	–	14
March 1979	–	6	–	8	–	6	–	–	20
TOTALS	2	30	27	16	2	66	77	6	226

Near Island Basin	
October 1978	49 Total

TABLE XLVI

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY April 1978. Mean Depth 28±6 meters

Number Examined: 18

Number Empty: 2

Percent Sex Composition: males=78%; females=22%

Percent Crab Class Composition[1]: 1=100%

Mean Width[2]: 75.7±22.8 mm

Number of Prey Taxa: 9

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Annelida	Polychaeta (segmented worms)	83	94	77.7	77.9
Mollusca	Pelecypoda (clams)	33	37	2.9	1.6
	Gastropoda (snails)	11	12	6.9	5.6
Arthropoda	*Crangon* spp. (shrimp)	11	12	6.6	5.3
	Decapoda	11	12	0.3	0.5

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

examined and accounted for nearly 78% of the weight and volume of the stomach contents, was the dominant prey. Other important prey such as pelecypods, gastropods, *Crangon* spp., shrimp, and unidentified decapod remains collectively made up only 16.7% of the total stomach biomass.

Snow crabs that were ≤ 40 mm also came from Stations 501 and 554. All 13 of the crabs examined contained food similar to that found in the adults. The most frequently consumed prey were polychaetes (53.8%), crustaceans remains (38.5%), gastropods (30.8%), and pelecypods (23.1%).

May 1978 (Table XLVII)

Snow crabs > 40 mm (mean width 106.9 ± 20.6 mm) came from Stations 2, 3, and 557. All were males and 98% had newshells.

Ten of the 45 crabs examined had empty stomachs. Twenty-seven different prey taxa were among the stomach contents. The dominant food items were arthropods, specifically, the snow crab (*Chionoecetes bairdi*) which accounted for 36.1% of the weight of the contents and 43% of the volume. Decapod remains made up 15.3% of the weight. Fishes were found in 26% of all stomachs or 34% of stomachs containing food, and accounted for 25.6% of the food biomass and 20.4% of the volume.

Seventy-two crabs were examined that were 40 mm or smaller. These crabs came from Stations 526, 527, and 557. Ninety percent of the crabs had food in their stomachs. The most frequently occurring items were sediment (44.4% of all stomachs examined), polychaetous annelids (36.1%), unidentified animal material (34.7%), and decapod remains (33.3%). The pelecypods *Nucula tenuis*, unidentified pelecypods, and *Axinopsida serricata* occurred in 26.4%, 25.0%, and 23.6% of the stomachs, respectively.

June 1978 (Table XLVIII)

The 101 snow crabs (110.5 ± 40.6 mm mean carapace width) that were examined in June came from five stations: 1 at Station 582, 21 at 554; 20 at 3; 19 at 7; and 40 at 8. Most (71%) of the crabs were males. The exoskeleton composition was 54% newshells and 46% oldshells.

TABLE XLVII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY May 1978. Mean Depth 80±9 meters

Number Examined: 45

Number Empty: 10

Percent Sex Composition: males=100%

Percent Crab Class Composition[1]: 1=97.8%; 2=2.2%

Mean Width[2]: 106.9±20.6 mm

Number of Prey Taxa: 27

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Chionoecetes bairdi* (snow crab)	13	17	36.1	43.2
	Decapoda	16	20	15.3	14.9
	Isopoda	11	14	5.2	4.8
Chordata	Pisces (fishes)	26	34	25.6	20.4
Unidentified animal material		44	57	5.7	5.6

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

TABLE XLVIII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY June 1978. Mean Depth 113±67 meters

Number Examined: 101

Number Empty: 24

Percent Sex Composition: males=71%; females=29%

Percent Crab Class Composition[1]: 1=53.5%; 2=46.5%

Mean Width[2]: 110.5±40.6 mm

Number of Prey Taxa: 38

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	Pandalidae (shrimp)	10	13	35.9	36.8
	Unid. shrimp	24	31	12.6	11.6
	Decapoda	10	13	13.4	13.8
Mollusca	*Axinopsida serricata* (clam)	24	31	3.3	4.0
	Macoma spp. (clam)	16	21	5.6	4.2
	Nucula tenuis (clam)	13	17	3.4	3.0
Chordata	Pisces (fishes)	22	29	6.1	5.3
Unidentified animal material		27	35	6.8	6.4

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

Seventy-six percent of the stomachs contained food, and 38 prey taxa were identified. Arthropods contributed most to the stomach weight and volume. Shrimps, i.e., pandalids and unidentified shrimp, accounted for 35.9% and 12.6% of the contents biomass, respectively. Decapods remains also yielded 13.4% of the food biomass. The clams *Axinopsida serricata*, *Macoma* spp., and *Nucula tenuis*, and unidentified fishes were all frequently found but each contributed little to the food weight or volume.

Snow crabs 40 mm or smaller were examined from Stations 526, 554, and 582. Only two out of 58 crabs had empty stomachs. The dominant stomach contents were sediment (66.1% frequency of occurrence in all stomachs examined), the clam *Axinopsida serricata* (56.9%), unidentified animal material (53.4%), fishes (48.3%), and unidentified clams (44.8%). A variety of other food items were found in lesser frequency.

July 1978 (Table IL)

Large snow crabs (mean carapace width 84.4 ± 29 mm) that were examined from 10 Izhut Bay stations in July were composed of 66 males and 34 females, of which 68 had newshells, and 32% had oldshell exoskeletons.

Thirteen of the 101 crabs contained food which consisted of 32 different prey taxa. The dominant prey was fishes; 38% frequency of occurrence among all stomachs examined, 37.4% of the food biomass, and 37.3% of the volume. Snow crabs were the second most important identifiable food item as they appeared in 18% of the stomachs, made up 7.9% of the food biomass and 7.5% of the volume. Two clams, *Axinopsida serricata* and *Nucula tenuis* were frequently taken but together made up only 4.2% of the biomass. Sediment was found in 75% of the crabs examined.

Only 20 crabs measuring 40 mm or smaller were examined. All were feeding. Unidentified animal material and sediment were found in 100% and 80% of the crabs, respectively. *Axinopsida serricata* occurred in 60% of the crabs, while foraminiferans, fishes, and snow crabs were found in 25%, 25%, and 20% of the stomachs, respectively.

TABLE IL

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY
July 1978. Mean Depth 88.6±50.3 meters

Number Examined: 101

Number Empty: 13

Percent Sex Composition: males=66%; females=34%

Percent Crab Class Composition[1]: 1=68.3%; 2=31.7%

Mean Width[2]: 84.4±29 mm

Number of Prey Taxa: 32

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Chordata	Pisces (fishes)	38	43	37.4	37.3
Arthropoda	*Chionoecetes bairdi* (snow crab)	18	20	7.9	7.5
Mollusca	*Axinopsida serricata* (clam)	25	28	2.8	2.5
	Nucula tenuis (clam)	19	22	1.4	1.3
Unidentified animal material		69	79	16.6	16.3
Sediment		75	86	7.4	8.3

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

August 1978 (Table L)

Only 31 snow crabs were examined from Izhut Bay in August. The mean size was 122 ± 33.5 mm. Twenty-seven males and 4 females were examined. Most (71%) crabs were newshells. Eleven crabs came from Station 6 and 20 crabs from Station 8.

Twenty-eight crabs contained food which consisted of 17 prey taxa. The dominant food was fishes which occurred in 61% of the crabs examined and accounted for 77.7% of the stomach contents weight and 77.3% of the volume. Unidentified animal material and sediment made up 13.3% and 2.6% of the food biomass, respectively. Although sediment was a small proportion of the biomass, it occurred in 74% of all stomachs examined.

No small snow crabs were examined.

November 1978 (Table LI)

Sampling from Izhut Bay Stations 7, 527, and 557 in November yielded 45 snow crabs > 40 mm (mean 99.8 ± 36.9 mm). Seventy-six percent were males and 24% were females. The exoskeleton composition was 78% newshells and 22% oldshells.

Twenty-eight prey taxa were identified among 41 feeding crabs. The most important prey was fishes which were found in 20% of the crabs examined and composed 45.8% of the food weight and 47.9% of the volume. Other food items i.e., shrimps, hermit crabs, snow crabs, and the clam *Axinopsida serricata*, were frequently found but each made up a small percentage of the biomass or volume. Sediment was found in 73% of the stomachs examined but yielded only 0.5% of the food weight.

The most frequently consumed identifiable food in 17 snow crabs measuring 40 mm or smaller was also fishes (88.2%). Other food items, in decreasing order of percent frequency of occurrence, were pelecypods (64.7%), ophiuroids (47.1%), decapods (29.4%), pectinarid polychaetes (23.5%), and *Axinopsida serricata* (23.5%). Unidentified animal remains and sediment each were present in 94.1% of the stomachs.

TABLE L

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY August 1978. Mean Depth 95±8.5 meters

Number Examined: 31

Number Empty: 3

Percent Sex Composition: males=87%; females=13%

Percent Crab Class Composition[1]: 1=70.9%; 2=29.0%

Mean Width[2]: 122±33.5 mm

Number of Prey Taxa: 17

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Chordata	Pisces (fishes)	61	68	77.7	77.3
Unidentified animal material		61	68	13.3	12.8
Sediment		74	82	2.6	3.1

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

TABLE LI

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY November 1978. Mean Depth 112.7±72.7 meters

Number Examined: 45

Number Empty: 4

Percent Sex Composition: males=76%; females=24%

Percent Crab Class Composition[1]: 1=77.7%; 2=22.2%

Mean Width[2]: 99.8±36.9 mm

Number of Prey Taxa: 28

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Chordata	Pisces (fishes)	20	22	45.8	47.9
Arthropoda	Unid. shrimp	20	22	5.9	2.7
	Paguridae (hermit crabs)	16	17	3.5	3.8
	Chionoecetes bairdi (snow crab)	11	12	4.5	3.2
Mollusca	*Axinopsida serricata* (clam)	27	29	1.7	2.1
Unidentified animal material		84	93	27.1	26.2
Sediment		73	80	0.5	1.4

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

BEST DOCUMENT AVAILABLE

March 1979 (Table LII)

Snow crabs that exceeded 40 mm in carapace width in March 1978 came from seven Izhut Bay stations: 19 from Station 678; 7 from 554; 4 from 551; 20 from 679; 14 from 557; 4 from 657; and 8 from 676. All were males, and the exoskeleton composition was 84% newshell and 16% oldshell.

Eighty-three percent of the crabs contained food which was identified as 28 different taxa. Important prey items were snow crabs and fishes. The percent frequency of occurrence of the latter items among all stomachs examined was 25% and 22%, respectively. Snow crabs and fishes also accounted for 20.3% and 12.6% of the food weight, respectively. Sediment was found in 74% of the crabs examined but accounted for only 2.1% of the food biomass.

The most frequently found identifiable food items in 20 small (≤40 mm) snow crabs were pelecypods (75%), amphipods (50%), clams of the family Nuculanidae (35%), and fishes (30%). Unidentified animal material and sediment occurred in 95% and 85% of the crabs, respectively.

Kiliuda Bay (Figure 2)

April 1978 (Table LIII)

Among the 10 snow crabs > 40 mm (67.8 ± 22.2 mm carapace width) that were examined from Kiliuda Bay in April 1978, six came from Station 580. Nine males and one female were examined. Most (90%) had newshell exoskeletons.

Nine crabs had 13 different prey taxa in their stomachs. Unidentified decapods and isopods dominated the stomach contents. Decapods occurred in 60% of the crabs examined and yielded 33.9% of the food biomass, and isopods were found in only 10% of the crab but accounted for 59.5% of the biomass. Pelecypods were a frequent food item (50%) but only made up 6.2% of the food weight.

The 54 smaller (≤40 mm) crabs most frequently consumed pelecypods (79.6%), polychaetes (33.3%), decapods (24.1%), fishes (22.2%), and echinoderms (20.4%). Unidentified animal material and sediment occurred in 74.1% and 51.9% of the stomachs, respectively.

TABLE LII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN IZHUT BAY March 1979. Mean Depth 36.7±20.8 meters

Number Examined: 76

Number Empty: 13

Percent Sex Composition: males=100%

Percent Crab Class Composition[1]: 1=84.2%; 2=15.8%

Mean Width[2]: 90.1±27.6 mm

Number of Prey Taxa: 28

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Chionoecetes bairdi* (snow crab)	25	30	20.3	20.4
Chordata	Pisces (fishes)	22	25	12.6	11.4
Unidentified animal material		80	97	50.4	50.0
Sediment		74	89	2.1	2.9

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

BEST DOCUMENT AVAILABLE

TABLE LIII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY April 1978. Mean Depth 46.2±36.8 meters

Number Examined: 10

Number Empty: 1

Percent Sex Composition: males=90%; females=10%

Percent Crab Class Composition[1]: 1=90%; 2=10%

Mean Width[2]: 67.8±22.2 mm

Number of Prey Taxa: 13

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	Decapoda	60	67	33.9	31.3
	Isopoda	10	11	59.5	62.0
Mollusca	Pelecypoda (clams)	50	56	6.2	4.7
Unidentified animal material		40	44	<0.1	0.4

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

June 1978 (Table LIV)

Nineteen snow crabs > 40 mm in carapace width (120.7 ± 49.7 mm) were examined in June. Most crabs came from Station SHR. The crabs were composed of 15 males and 4 females, of which 95% were newshells and 5% were oldshells.

Thirteen crabs contained food, and 18 different food taxa were identified. The biomass of the stomach contents was dominated by shrimp (60.4%), presumably all *Pandalus borealis*. Unidentified crabs occurred in 26% of the crabs but only made up 5.8% of the biomass. Fishes also contributed 28.3% of the food weight. The two pelecypods, *Nucula tenuis* and *Axinopsida serricata*, each occurred in 21% of the crabs examined but only accounted for 2.5% and 0.9% of the biomass, respectively.

Small snow crabs ($\leq$40 mm) most frequently contained the clam *Axinopsida serricata* (52%), spionid polychaetes (37.8%), the clam *Nucula tenuis* (28.6%), unidentified crabs (20.4%), foraminiferans (14.3%) and fishes (10.2%). Sediment occurred in 58.2% of the stomachs.

July 1978 (Table LV)

The number of snow crabs > 40 mm that were examined in July was 31, 27 males and 4 females. Most came from Stations 6 and SHR. The exoskeleton composition was 68% newshells and 32% oldshells.

Twenty-four crabs contained food; 15 prey taxa were identified. The dominant prey in July was similar to that found in June i.e., shrimps and fishes. Unidentified shrimps occurred in 42% of the crabs examined and made up 30.1% of the food weight. Fishes were only found in 10 crabs but contributed the most to the food biomass i.e., 45.2%. Snow crabs were also found in 10% of the crab stomachs, but they only accounted for 4.7% of the food weight. Sediment was commonly found but made up little of the overall biomass.

No single food item dominated in the food of 20 small snow crabs ($\leq$40 mm). Sediment occurred in 65% of the crabs, foraminiferans in 35%, and *Pinnixa* sp. crabs in 20%. A variety of clams and arthropods were also found.

TABLE LIV

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY June 1978. Mean Depth 45.7±39.3 meters

Number Examined: 19

Number Empty: 6

Percent Sex Composition: males=79%; females=21%

Percent Crab Class Composition[1]: 1=94.7%; 2=5.3%

Mean Width[2]: 120.7±49.7 mm

Number of Prey Taxa: 18

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Pandalus borealis* (pink shrimp)	5	8	30.4	29.9
	Pandalus sp. (shrimp)	5	8	30.0	33.7
	Unid. crab	26	38	5.8	5.6
Chordata	Pisces (fishes)	10	15	28.3	18.7
Mollusca	*Nucula tenuis* (clam)	21	31	2.5	3.9
	Axinopsida serricata (clam)	21	31	0.9	3.0

---

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

BEST DOCUMENT AVAILABLE

TABLE LV

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY
July 1978. Mean Depth 69.5±29.7 meters

Number Examined: 31

Number Empty: 7

Percent Sex Composition: males=87%; females=13%

Percent Crab Class Composition[1]: 1=67.7%; 2=32.3%

Mean Width[2]: 104.5±39.7 mm

Number of Prey Taxa: 15

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	Unid. shrimp	42	54	30.1	31.6
	Chionoecetes bairdi (snow crab)	10	12	4.7	3.9
Chordata	Pisces (fishes)	10	12	45.2	43.0
Unidentified animal material		55	71	15.9	15.7
Sediment		23	29	0.7	1.2

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

August 1978 (Table LVI)

Only 15 snow crabs that exceeded 40 mm in width were examined from four Kiliuda Bay stations in August. The sex composition was 73% males and 27% females. Exoskeleton composition was 73% newshells and 27% oldshells.

Twenty-three different prey taxa were identified among 12 crabs containing food. Dominant prey were the clams *Macoma* spp. and *Axinopsida serricata*, which occurred in 13% and 33%, respectively. *Macoma* spp. contributed 38.8% of the food biomass while *Axinopsida* only contributed 6.6%. Sediment was found in 73% of the crabs.

The most frequently consumed items in the 20 snow crabs 40 mm or smaller were *Axinopsida serricata* (50%), foraminiferans (35%), the clam *Nucula tenuis* (35%), and snow crabs (30%).

November 1978 (Table LVII)

Large snow crabs (133.5 ± 31.4 mm mean carapace width) examined in November totaled 36; 34 males and 2 females. Most crabs came from Stations 5, 7 and SHR. The exoskeleton composition was 47% newshells and 53% oldshells.

The dominant prey among the 32 feeding crabs was the clam *Macoma* spp. which occurred in 39% of the crabs and made up 28.7% of the food biomass. Snow crabs, shrimp and fishes were frequently found (19-31%) but each accounted for less than 9% of the food weight. Again, sediment was frequently found but made up little of the total biomass.

Frequently occurring prey in 14 crabs measuring 40 mm or less were foraminiferans (64.3%), pelecypods (57.1%), fishes (50%), *Axinopsida serricata* (42.9%), and ophiuroids (35.7%).

March 1979 (Table LVIII)

March 1979 sampling yielded 31 large snow crabs (91.6 ± 39.5 mm) for stomach analysis. Crabs came from six stations. Most crabs were males (81%) and most had newshells (87%).

TABLE LVI

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY
August 1978. Mean Depth 47.5±33.5 meters

Number Examined: 15

Number Empty: 3

Percent Sex Composition: males=73%; females=27%

Percent Crab Class Composition[1]: 1=73.3%; 3=26.7%

Mean Width[2]: 96.7±54.3 mm

Number of Prey Taxa: 23

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	13	17	38.8	34.7
	Axinopsida serricata (clam)	33	42	6.6	5.6
Unidentified animal material		80	100	35.8	35.7
Sediment		73	92	4.5	3.6

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

TABLE LVII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY November 1978. Mean Depth 61.6±33.8 meters

Number Examined: 36

Number Empty: 4

Percent Sex Composition: males=94%; females=6%

Percent Crab Class Composition[1]: 1=47.2%; 2=52.8%

Mean Width[2]: 133.5±31.4 mm

Number of Prey Taxa: 23

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	39	44	28.7	25.2
Arthropoda	Unid. shrimp	22	25	5.9	6.1
	Chionoecetes bairdi (snow crab)	19	22	6.4	5.0
Chordata	Pisces (fishes)	31	34	8.6	9.0
Unidentified animal material		81	91	30.0	34.0
Sediment		72	81	5.2	5.4

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

TABLE LVIII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS IN KILIUDA BAY March 1979. Mean Depth 47.2±24.3 meters

Number Examined: 31

Number Empty: 4

Percent Sex Composition: males=81%; females=19%

Percent Crab Class Composition[1]: 1=87.1%; 2=12.9%

Mean Width[2]: 91.6±39.5

Number of Prey Taxa: 17

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Chionoecetes bairdi* (snow crab)	19	22	20.3	26.1
	Unid. crab	29	33	7.9	10.9
Chordata	Pisces (fishes)	39	44	18.0	24.7
Mollusca	*Axinopsida serricata* (clam)	23	26	1.3	2.0
	Nuculanidae (clam)	13	15	3.5	3.4
Unidentified animal material		77	89	44.6	25.4
Sediment		58	67	<0.1	0.8

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

The 27 feeding crabs contained a total of 17 different prey taxa. Dominant prey were crabs and fishes. Snow crabs occurred in 19% of the crabs and made up 20.3% of the biomass. Unidentified crabs were also found (29% frequency of occurrence), but only accounted for 7.9% of the food weight. Fishes were more frequently found (39%) and contributed 18% of the food weight. The clam *Axinopsida serricata* and clams of the family Nuculanidae were frequently found but accounted for little of the overall biomass. Sediment was frequent among the stomach contents.

The 20 small snow crabs ($\leq$40 mm in width) most frequently consumed foraminiferans (35%), fishes (35%), pelecypods (25%), and crustaceans (25%).

Kodiak Shelf

March 1978 (Table LIX; Figure 4)

Eighty-eight snow crabs > 40 mm (carapace width) were examined from Stations 2, 8, 10, 20, and 26 located east of Afognak Island near Portlock Bank. Newshell males dominated.

Seventy-six percent of the crabs examined contained food; 28 taxa were identified. Arthropods, pelecypods, and polychaetes were the main food items found. Unidentified decapods, hermit crabs, pelecypods, and polychaetes accounted for 31.3, 10.9, 23.3, and 8.5% of the food weight, respectively.

No crabs smaller than 40 mm were examined.

June-July 1978 (Tables LX and LXI; Figure 5)

During the June-July 1978 Kodiak Shelf sampling 167 snow crabs > 40 mm (mean carapace width 139 ± 25 mm) were examined for stomach contents. Males predominated and the exoskeleton composition was 53% newshells and 47% oldshells.

One hundred and thirty-six crabs contained food, and 43 food taxa were identified. Clams, shrimps and crabs were the most important prey. Clams of the genera *Macoma* were most frequently taken (22%) and made up 13.6% of the food weight. *Macoma* spp. was dominant prey at Stations 7, 9, and 12. Another clam, genera *Yoldia*, was also a dominant prey and was taken mainly

TABLE LIX

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS ON THE KODIAK SHELF
March 1978. Mean Depth 101±38.8 meters

Number Examined: 88

Number Empty: 21

Percent Sex Composition: males=78%; females=22%

Percent Crab Class Composition[1]: 1=94.3%; 2=5.7%

Mean Width[2]: 109±44.1 mm

Number of Prey Taxa: 28

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	Decapoda	24	31	31.3	31.7
	Paguridae (hermit crab)	7	9	10.9	9.1
Mollusca	Pelecypoda (clams)	43	57	23.3	23.3
Annelida	Polychaeta (segmented worms)	18	24	8.5	10.5

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

TABLE LX

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS ON THE KODIAK SHELF June-July 1978. Mean Depth 126.3±40.3 meters

Number Examined: 167

Number Empty: 31

Percent Sex Composition: males=96%; females=4%

Percent Crab Class Composition[1]: 1=53.3%; 2=46.7%

Mean Width[2]: 139±25 mm

Number of Prey Taxa: 43

DOMINANT PREY

		% Freq. Occurrence based on			
Phylum	Species[3]	Total stomachs	Stomachs w/food	% by Weight	% by Volume
Mollusca	*Macoma* spp. (clam)	22	27	13.6	11.2
	Yoldia spp. (clam)	12	15	7.8	6.7
	Axinopsida serricata (clam)	7	9	1.9	1.7
Arthropoda	Unid. shrimp	23	29	14.4	15.4
	Chionoecetes bairdi (snow crab)	11	13	5.0	5.0
Unidentified animal material		66	82	26.0	28.9
Sediment		49	60	1.3	1.8

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

BEST DOCUMENT AVAILABLE

TABLE LXI

STATION DATA AND STOMACH CONTENTS OF SNOW CRABS COLLECTED ON THE KODIAK SHELF
June-July 1978

Station Name	4	7	8	9
$\bar{x}$ Depth, m	141	56	73	140
Number Examined	15	20	20	16
Number Empty	4	6	7	1
% Composition[1]	2=100%	2=100%	1=100%	1=62.5%; 2=37.5%
Prey Taxa	19	15	11	21
Dominant prey-% wt.	*Chionoecetes bairdi*-22.1 Pieces-9.7 Unid. crab-9.4 Unid. animal-23.5 Sediment-11.6	*Macoma* spp.-40.2 *Nuculana* spp.-18.1 Unid. animal-26.2	*Yoldia* spp.-31.6 *Nuculana* spp.-25.9 *Nucula tenuis*-4.2 Unid. animal-27.9	*Macoma* spp.-20.0 *Axinopsida serricata*-9.3 *Chionoecetes bairdi*-6.2 *Nucula tenuis*-6.3

Station Name	10	11	12	13	14
$\bar{x}$ Depth, m	126	117	135	173	176
Number Examined	16	20	20	20	20
Number Empty	3	4	0	4	2
% Composition[1]	2=100%	2=100%	1=100%	1=100%	1=95%; 2=5%
Prey Taxa	11	16	18	11	14
Dominant prey-% wt.	Unid. animal-81.9 Hippolytidae-17.8	*Chionoecetes bairdi*-32.1 *Pandalus borealis*-25.8 Unid. shrimp-14.8	*Macoma* spp.-34.9 *Yoldia* spp.-19.1 *Pinnixa* spp.-8.0 Unid. animal-25.0	Unid. shrimp-63.5 *Pandalus* spp.-11.3 Unid. animal-15.5	Paguridae-28.8 Unid. shrimp-24.4 *Pandalus* spp.-16.9 Unid. animal-22.1

---

[1] see methods for description of crab classes

at Stations 8 and 12. This bivalve made up 7.8% of the food weight and occurred in 12% of the crabs examined. *Axinopsida serricata* was a clam of lesser importance; 7% frequency of occurrence and 1.9% by weight. Unidentified shrimps were found in 23.% of the crabs examined and contributed 14.4% of the food biomass. Eleven percent of the stomachs contained snow crabs; 5.0% by weight. Sediment occurred in 49% of the stomachs.

No crabs smaller than 40 mm were examined.

February 1979 (Tables LXII and LXIII; Figure 5)

Snow crabs (211) that were examined in February 1979 came from 11 stations. All were newshell males and had a mean carapace width of 145.1 ± 18.7 mm.

Ninety-one percent of all crabs contained food; 47 food taxa were identified. Crabs were the dominant prey comprising 36.2% of the food biomass. *Chionoecetes bairdi* (snow crab) and *Pinnixa* spp. (pea crab) were most important and occurred mainly at Stations 44, 4, 8, 7, 55, and 10 and 11, respectively. Clams, mainly *Macoma* spp. and individuals of the family Nuculanidae were frequently found in the stomachs but only made up 7.6% of the biomass. Fishes occurred in 18% of the crabs and yielded 6.3% of the biomass. Sediment was frequently found (57%) but made up less than 0.1% of the biomass.

Near Island Basin (Figure 3)

October 1978 (Appendix B - Table II)

The most frequently occurring identifiable food items in the 49 small (≤40 mm), SCUBA-caught snow crabs were the gastropod *Lacuna variegata* (61.2% among all snow crabs examined), unidentified pelecypods (59.2%), the clam *Axinopsida serricata* (57.1%), and amphipods (30.6%). Sediment and unidentifiable animal material occurred in 77.6% and 98% of the stomachs, respectively. Thirteen other pray taxa were identified.

TABLE LXII

STOMACH CONTENTS OF SNOW CRABS COLLECTED *VIA* TRAWLS ON THE KODIAK SHELF February 1979. Mean Depth 127±47.5 meters

Number Examined: 211

Number Empty: 20

Percent Sex Composition: males=100%

Percent Crab Class Composition[1]: 1=100%

Mean Width[2]: 145.1±18.7 mm

Number of Prey Taxa: 47

DOMINANT PREY

Phylum	Species[3]	% Freq. Occurrence based on Total stomachs	% Freq. Occurrence based on Stomachs w/food	% by Weight	% by Volume
Arthropoda	*Chionoecetes bairdi* (snow crab)	20	22	14.9	15.1
	Pinnixa spp. (pea crab)	15	16	7.9	8.1
	Unid. crab	16	17	13.4	13.7
Mollusca	*Macoma* spp. (clam)	21	24	4.4	3.5
	Nuculanidae (clams)	20	22	2.5	2.4
	Pelecypoda (unid. clams)	30	33	0.7	1.0
Chordata	Pisces (fishes)	18	20	6.3	6.1
Echiura	Echiuridae (spoon worm)	20	22	0.5	0.5
Unidentified animal material		82	91	43.5	42.8
Sediment		57	63	<0.1	0.4

[1] see methods for description of crab classes

[2] based on all stomachs examined

[3] species or lowest level of identification

BEST DOCUMENT AVAILABLE

TABLE LXIII

STATION DATA AND STOMACH CONTENTS OF SNOW CRAB
KODIAK SHELF
February 1979

Station Name	44	4	8	7
$\bar{X}$ Depth, m	151	152	70	53
Number Examined	20	20	20	20
Number Empty	0	2	4	4
% Composition[1]	1=100%	1=100%	1=100%	1=100%
Prey Taxa	19	20	14	11
Dominant prey-% wt.	Pisces-6.7 *Chionoecetes bairdi*-5.9 Unid. crab-6.6 *Macoma* spp.-4.9 Unid. animal-68.6	*Chionoecetes bairdi*-27.9 Polychaeta-6.3 Pisces-1.5 Unid. animal-12.0	*Chionoecetes bairdi*-48.8 Unid. crab-32.4 Pisces-3.8 Unid. animal-12.8	*Chionoecetes bairdi*-45.7 Unid. crab-33.6 *Macoma* spp.-5.5 Unid. animal-12.7

Station Name	12	S5	23	14
$\bar{X}$ Depth, m	135	197	57	165
Number Examined	20	20	19	20
Number Empty	0	0	4	2
% Composition[1]	1=100%	1=100%	1=100%	1=100%
Prey Taxa	22	22	22	21
Dominant prey-% wt.	*Macoma* spp.-32.2 Nephtyidae-25.7 *Yoldia* spp.-14.8 *Nuculana* spp.-9.2 Unid. animal-10.9	Pisces-28.9 *Chionoecetes bairdi*-19.0 Polychaeta-7.6 Unid. animal-37.1	Unid. crab-36.6 Pisces-6.7 Echiuridae-2.3 Unid. animal-50.6	Pisces-32.1 *Macoma* spp.-11.8 Unid. animal-48.5

Station Name	10	11	S3
$\bar{X}$ Depth, m	128	125	164
Number Examined	20	20	12
Number Empty	1	2	1
% Composition[1]	1=100%	1=100%	1=100%
Prey Taxa	21	21	13
Dominant prey-% wt.	*Pinnixa* spp.-16.1 *Chionoecetes bairdi*-20.1 Unid. animal-61.1	*Pinnixa occidentalis*-31.6 Pisces-5.0 Unid. animal-62.1	Unid. crab-42.4 Pisces-8.5 Unid. animal-44.6

---

[1] see methods for description of crab classes

Statistical Analysis

Snow crab food

The Wilcoxon Rank Sum Test was employed to test the difference in the quantity of various food groups consumed between sexes. The test revealed no significant difference ($P = 0.220$) in amount of food consumed by males and females (Table LXIV).

When the sexes were combined, Crustacea dominated the food weight. Pisces and Mollusca were the second and third most important food groups, in terms of food weight (Table LXV). In terms of frequency of occurrence, molluscs and crustaceans dominated; fishes and annelids followed. The food groups Annelida, plant material and Echinodermata contributed little (3.3%) to the overall food weight. Sediment occurred in 47.1% of all crabs examined but only accounted for 8.7% of the weight.

The mean amount of prey consumed by feeding crabs > 40 mm was 0.81 g/crab.

Snow crab food *versus* crab size

Most of the eight crab size groups each contained from 9-21% of all crabs examined. The largest group (180-192 mm) only contained 1% of all crabs. The Friedman Analysis of Variance Test was employed to test each weight the major food categories among size groups. The test revealed no significant differences at $\alpha = 0.05$ (Table LXVI).

When the Kruskal-Wallis Test was employed on the weight of consumed food by crabs of various size groups, significant differences were detected in both all crabs and feeding crabs (Table LXVII). Among all crabs 40-59 mm crabs consumed significantly less food than 160-179 mm crabs. Seven pairs were different among feeding crabs. Most of these pairs were small crabs (<100 mm) *versus* large crabs (>100 mm). The small crabs contained significantly less food than large crabs.

Snow crab food *versus* crab class

When the amount of food consumed by newshell and oldshell crabs were compared by the Mann-Whitney Test (Zar, 1974), significant differences were detected in both all crabs examined and crabs that had food in their stomachs (Table LXVIII). By examining the mean rank sum values, we conclude that newshell crabs consumed a significantly greater ($P < 0.05$) amount of food than oldshell crabs.

TABLE LXIV

DATA EMPLOYED IN THE WILCOXON RANK SUM TEST FOR CONSIDERATION OF DIFFERENCE BETWEEN AMOUNT OF FOOD CONSUMED BETWEEN SEXES OF SNOW CRABS

Values are median food weights

Food Group	Male	Female
Plant	0.001	0.001
Annelida	0.020	0.001
Mollusca	0.001	0.002
Arthropoda	0.001	0.003
Echinodermata	0.002	0.001
Pisces	0.003	0.001

TABLE LXV

SUMMARY OF THE STOMACH CONTENTS OF *CHIONOECETES BAIRDI* FOR 1025 CRABS EXAMINED >40 mm

Food category	Food wet weight Total (g)	Percent	Percent frequency of occurrence
Crustacea	253.60	36.6	46.9
Pisces	95.70	13.8	21.4
Mollusca	84.30	12.2	46.8
Annelida	20.61	3.0	18.1
Plant	2.03	0.3	4.8
Echinodermata	0.86	0.1	6.0
Unid. animal material	226.76	32.7	59.7
Unid. material	0.36	0.1	12.0
Sediment	8.72	1.3	47.1
Total wet weight	692.94	100.0	

TABLE LXVI

SUMMARY OF STOMACH CONTENTS OF 1025 *CHIONOECETES BAIRDI* BY SIZE GROUPS

(A) Total wet weight (g) of each food category; (B) gravimetric percent of each food category; and (C) percent frequency of occurrence

Size group	I			II			III			IV		
Carapace width, mm	40-59			60-79			80-99			100-119		
Sample size	125			88			113			130		
Food category	A	B	C	A	B	C	A	B	C	A	B	C
Crustacea	7.19	53.9	50	9.36	57.5	59	16.86	53.3	47	31.94	63.9	44
Pisces	0.38	2.8	18	1.51	9.3	26	6.00	19.0	28	13.41	26.8	28
Mollusca	3.59	26.9	69	3.84	23.6	67	4.85	15.3	46	3.79	7.6	26
Annelida	1.51	11.3	27	1.30	8.0	28	3.88	12.3	21	0.75	1.5	13
Plant	0.09	0.7	10	0.20	1.2	8	0.03	0.1	8	0.08	0.2	5
Echinodermata	0.59	4.4	18	0.06	0.4	12	0.02	0.1	8	<0.01	<0.1	5

Size group	V			VI			VII			VIII		
Carapace width, mm	120-139			140-159			160-179			180-192		
Sample size	217			219			125			8		
Food category	A	B	C	A	B	C	A	B	C	A	B	C
Crustacea	66.40	59.0	48	74.65	54.8	46	47.19	49.5	41	0	0	0
Pisces	20.81	18.5	18	32.44	23.8	17	21.06	22.1	22	0.09	5.4	12
Mollusca	13.51	12.0	43	27.79	20.4	47	25.33	26.6	39	1.59	94.6	50
Annelida	10.93	9.7	21	1.01	0.7	11	1.23	1.3	12	0	0	0
Plant	0.76	0.7	1	0.44	0.3	3	0.42	0.4	3	0	0	0
Echinodermata	0.10	0.1	3	<0.01	<0.1	<1	0.08	0.1	4	0	0	0

TABLE LXVII

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR SNOW CRAB FOOD WEIGHT AND CRAB SIZE GROUPS

Size (mm)	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
40- 59	125	54828.5	112	34914.0
60- 79	88	43856.0	79	29823.5
80- 99	113	60096.0	103	41947.0
100-119	130	64465.5	102	44963.5
120-139	217	109330.0	180	75963.5
140-159	219	116084.5	174	83050.0
160-179	125	74081.0	101	55085.0
180-192	8	3083.5	6	1906.5

Pairs significantly different ($P<0.05$)

Stomachs examined	Stomachs w/food
40- 59 < 160-179	40- 59 < 100-119
	40- 59 < 120-139
	40- 59 < 140-159
	40- 59 < 160-179
	60- 79 < 160-179
	80- 99 < 160-179
	120-139 < 160-179

---

[1] critical Kruskal-Wallis test statistic = 20.57
calculated P-value = 0.004 assuming a χ^2 distribution with 7 d.f.

[2] critical Kruskal-Wallis test statistic = 59.98
calculated P-value ≈ 0 assuming a χ^2 distribution with 7 d.f.

TABLE LXVIII

MANN-WHITNEY ONE-WAY ANALYSIS OF VARIANCE FOR SNOW CRAB FOOD WEIGHT AND CRAB CLASS

Crab class	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
Newshell	643	347328.5	555	246652.5
Oldshell	382	178496.5	302	121000.5

---

[1] critical Mann-Whitney test statistic = 140282
calculated P-value ≈ 0 assuming normal distribution (one-tail)

[2] critical Mann-Whitney test statistic = 92362
calculated P-value = 0.006 assuming normal distribution (one-tail)

Snow crab food *versus* sampling period

The effect of sampling periods on the amount of food consumed by two categories of snow crabs (all crabs and feeding crabs) was examined by the Kruskal-Wallis Test. A significant difference in the amount of food consumed between months was detected for both crab categories (Table LXIX). The six pairs that were different in feeding crabs revealed that crabs from March, May, June and July 1978 contained less food than crabs from November 1978 and February 1979. The pattern in the six different pairs among all crabs were also seasonally distinct.

Snow crab food *versus* sampling area

When the food weight from all and only feeding snow crabs were compared between three sampling areas the Kruskal-Wallis Test revealed a significant difference (Table LXX). Differences in both crab groups revealed that crabs from Izhut Bay contained less food than crabs from the Kodiak Shelf.

Snow crab food *versus* depth

The Kruskal-Wallis Test revealed that the amount of food consumed by all crabs examined was similar at eight different depth strata. However, a significant difference was detected when considering only crabs with food in their stomachs. Crabs at 26-50 m contained less food than crab from 126-150 m (Table LXXI).

Pandalus borealis (Pink Shrimp)

A total of 1300 pink shrimps were examined for food contents in the present study (Table LXXII). Shrimps came from stations in Izhut Bay, Kiliuda Bay, and the outer Kodiak shelf. Stomach contents of pink shrimp from Izhut and Kiliuda Bays were similar. The items which most frequently occurred in these bays, in decreasing order, were sediment, diatoms, crustaceans remains, and foraminiferans. A variety of diatoms were found, however, most were only identified as Centrales or Pennales. Crustacea were mainly identified as shrimp, Decapoda, or unidentified Crustacea. Occasionally, whole or fragmented ostracods, harpactacoid copepods, amphipods,

TABLE LXIX

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR SNOW CRAB FOOD WEIGHT AND SAMPLING PERIOD

Sampling period	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
Mar. 1978	88	34773.5	66	21826.5
Apr. 1978	28	13906.5	25	9453.0
May 1978	45	19049.0	35	12324.0
Jun. 1978	135	54477.5	101	34636.5
Jul. 1978	284	143341.5	236	99637.5
Aug. 1978	46	25433.5	40	18206.5
Nov. 1978	81	47896.5	73	34956.5
Feb. 1979	211	131080.0	191	97302.0
Mar. 1979	107	55867.0	90	39310.5

Pairs significantly different ($P<0.05$)

Stomachs examined	Stomachs w/food
Mar. 1978 < Nov. 1978	Mar. 1978 < Nov. 1978
Mar. 1978 < Feb. 1979	Mar. 1978 < Feb. 1979
May 1978 < Feb. 1979	May 1978 < Feb. 1979
Jun. 1978 < Nov. 1978	Jun. 1978 < Nov. 1978
Jun. 1978 < Feb. 1979	Jun. 1978 < Feb. 1979
Jul. 1978 < Feb. 1979	Jul. 1978 < Feb. 1979

---

[1] critical Kruskal-Wallis test statistic = 72.03
calculated P-value ≈ 0 assuming a χ^2 distribution with 8 d.f.

[2] critical Kruskal-Wallis test statistic = 50.96
calculated P-value ≈ 0 assuming a χ^2 distribution with 8 d.f.

TABLE LXX

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR SNOW CRAB FOOD WEIGHT AND SAMPLING AREA

Sample area	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
Izhut Bay	417	202840.5	347	138629.5
Kiliuda Bay	142	70939.5	117	49171.0
Kodiak Shelf	466	252045.0	393	179852.5

Pairs significantly different ($P<0.05$)	
Stomachs examined	Stomachs w/food
Izhut Bay < Kodiak Shelf	Izhut Bay < Kodiak Shelf

---

[1] critical Kruskal-Wallis test statistic = 7.82
calculated P-value = 0.02 assuming a χ^2 distribution with 2 d.f.

[2] critical Kruskal-Wallis test statistic = 10.34
calculated P-value = 0.005 assuming a χ^2 distribution with 2 d.f.

TABLE LXXI

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR SNOW CRAB FOOD WEIGHT AND DEPTH

Depth (m)	Stomachs examined	Rank sum[1] of contents	Stomachs w/food	Rank sum[2] of contents
0- 25	35	17148.5	31	11602.5
26- 50	121	58340.0	107	39181.0
51- 75	207	102241.5	159	71473.5
76-100	242	123049.0	199	85983.5
101-125	78	40968.0	65	28949.5
126-150	107	64314.0	98	47089.5
151-175	102	54056.0	91	47838.5
176-197	133	65708.0	107	45535.0

Pairs significantly different ($P<0.05$)

Stomachs w/food

26-50 < 126-150

---

[1] critical Kruskal-Wallis test statistic = 12.99
calculated P-value = 0.07 assuming a χ^2 distribution with 7 d.f.

[2] critical Kruskal-Wallis test statistic = 14.35
calculated P-value = 0.04 assuming a χ^2 distribution with 7 d.f.

TABLE LXXII

DOMINANT STOMACH CONTENTS OF PINK SHRIMP (*PANDALUS BOREALIS*) FROM THE KODIAK ISLAND REGION, 1978-79

(N) = Number of Stomachs

Stomach contents	Percent frequency of occurrence based on	
	Total stomachs	Stomachs w/food
Izhut Bay - Sta. 557 - May 1978	N = 100	N = 84
Sediment	82.0	97.6
Unid. Crustacea	51.0	60.7
Animal material	39.0	46.4
Shrimp	24.0	28.6
Foraminifera	21.0	25.0
Centrales (diatoms)	21.0	25.0
Izhut Bay - Sta. 554, 7 - June 1978	N = 100	N = 91
Sediment	84.0	92.3
Unid. Crustacea	67.0	73.6
Centrales (diatoms)	55.0	60.4
Pennales (diatoms)	42.0	46.1
Foraminifera	39.0	42.8
Animal material	26.0	28.6
Chaetoceros spp. (diatoms)	23.0	25.3
Polychaeta	21.0	23.1
Brebissonia sp. (diatoms)	18.0	19.8
Melosira sulcata (diatoms)	14.0	15.4
Plant material	12.0	13.2
Capitellidae (Polychaeta)	10.0	11.0
Izhut Bay - Sta. 526, 557 - July 1978	N = 99	N = 81
Sediment	79.8	97.5
Unid. Crustacea	55.6	67.9
Centrales (diatoms)	30.3	37.0
Foraminifera	21.2	25.9
Plant material	21.2	25.9
Animal material	18.2	22.2
Unid. material	17.2	21.0
Pennales (diatoms)	14.1	17.3
Polychaeta	13.1	16.0
Rhizosolenia spp. (diatoms)	12.1	25.9
Izhut Bay - Sta. 557 - August 1978	N = 100	N = 87
Sediment	82.0	94.2
Centrales (diatoms)	81.0	93.1

TABLE LXXII

CONTINUED

Stomach contents	Percent frequency of occurrence based on Total stomachs	Stomachs w/food
Unid. Crustacea	81.0	93.1
Tintinnidae (Protozoa)	58.0	66.7
Pennales (diatoms)	51.0	58.6
Rhizosolenia spp. (diatoms)	44.0	50.6
Chaetoceros spp. (diatoms)	27.0	31.0
Foraminifera	23.0	26.4
Protozoa	22.0	25.3
Polychaeta	15.0	17.2
Spionidae (Polychaeta)	10.0	11.5
Izhut Bay - Sta. 679 - March 1979	N = 100	N = 76
Sediment	70.0	92.1
Unid. Crustacea	37.0	48.7
Animal material	36.0	47.4
Unid. material	20.0	26.3
Centrales (diatoms)	18.0	23.7
Shrimp	12.0	15.8
Foraminifera	11.0	14.5
Pisces	8.0	10.5
Bivalvia	9.0	11.8
Kiliuda Bay - Sta. SHR - June 1978	N = 100	N = 98
Sediment	95.0	96.9
Unid. Crustacea	94.0	95.9
Centrales (diatoms)	88.0	89.8
Pennales (diatoms)	77.0	78.6
Decapoda	50.0	51.0
Foraminifera	45.0	45.9
Plant material	41.0	41.8
Chaetoceros spp. (diatoms)	31.0	31.6
Polychaeta	20.0	20.4
Bivalvia	13.0	13.3
Shrimp	12.0	12.2
Kiliuda Bay - Sta. SHR - July 1978	N = 101	N = 99
Centrales (diatoms)	95.0	97.0
Sediment	94.1	96.0
Rhizosolenia spp. (diatoms)	88.1	89.9

TABLE LXXII

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Total stomachs	Stomachs w/food
Unid. Crustacea	75.2	76.8
Pennales (diatoms)	68.3	69.7
Chaetoceros spp. (diatoms)	65.3	66.7
Polychaeta	55.4	56.6
Foraminifera	54.5	55.6
Stephanopyxis spp. (diatoms)	40.6	41.4
Decapoda	40.6	41.4
Brebissonia (diatoms)	36.6	37.4
Tintinnidae (Protozoa)	25.7	26.3
Naviculaceae (diatoms)	20.8	21.2
Bivalvia	20.8	21.2
Plant material	16.8	17.2
Spionidae (Polychaeta)	15.8	16.2
Shrimp	11.9	12.1
Kiliuda Bay - Sta. SHR - August 1978	N = 100	N = 65
Sediment	62.0	95.4
Unid. Crustacea	50.0	76.9
Tintinnidae (Protozoa)	42.0	64.6
Centrales (diatoms)	35.0	53.8
Polychaeta	23.0	35.4
Rhizosolenia spp. (diatoms)	21.0	32.3
Shrimp	16.0	24.6
Pennales (diatoms)	15.0	23.1
Animal material	11.0	16.9
Chaetoceros spp. (diatoms)	10.0	15.4
Foraminifera	9.0	13.8
Decapoda	9.0	13.8
Kiliuda Bay - Sta. SHR - November 1978	N = 100	N = 100
Centrales (diatoms)	100.0	100.0
Sediment	92.0	92.0
Pennales (diatoms)	81.0	81.0
Foraminifera	75.0	75.0
Unid. Crustacea	73.0	73.0
Chaetoceros spp. (diatoms)	64.0	64.0
Polychaeta	47.0	47.0
Rhizosolenia spp. (diatoms)	40.0	40.0
Brebissonia (diatoms)	39.0	39.0
Plant material	22.0	22.0

TABLE LXXII

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Total stomachs	Stomachs w/food
Navicula spp. (diatoms)	20.0	20.0
Decapoda	17.0	17.0
Tintinnidae (Protozoa)	15.0	15.0
Grammatophora spp. (diatoms)	10.0	10.0
Naviculaceae (diatoms)	10.0	10.0
Kiliuda Bay - Sta. 676 - March 1979	N = 100	N = 87
Sediment	85.0	97.7
Foraminifera	49.0	56.3
Unid. Crustacea	45.0	51.7
Capitellidae (Polychaeta)	35.0	40.2
Shrimp	30.0	34.5
Animal material	29.0	33.3
Centrales (diatoms)	28.0	32.2
Bivalvia	14.0	16.1
Unid. material	13.0	14.9
Polychaeta	10.0	11.5
Pisces	10.0	11.5
Kodiak Shelf - Sta. 7, 8, 13, 14 - June-July 1978	N = 200	N = 174
Sediment	82.5	94.8
Unid. Crustacea	43.5	50.0
Decapoda	27.0	31.0
Shrimp	27.0	31.0
Foraminifera	26.0	29.9
Bivalvia	25.5	29.3
Animal material	21.0	24.1
Centrales (diatoms)	20.5	23.6
Protozoa	15.0	17.2
Polychaeta	14.5	16.7
Pisces	12.5	14.4
Unid. material	11.0	12.6
Spionidae (Polychaeta)	9.5	10.9
Kodiak Shelf - Sta. 14 - February 1979	N = 100	N = 82
Sediment	72.0	87.8
Unid. material	49.0	59.8
Pisces	38.0	46.3

BEST DOCUMENT AVAILABLE

TABLE LXXII

CONTINUED

Stomach contents	Percent frequency of occurrence based on Total stomachs	Percent frequency of occurrence based on Stomachs w/food
Unid. Crustacea	35.0	42.7
Animal material	33.0	40.2
Centrales (diatoms)	25.0	30.5
Foraminifera	10.0	12.2
Shrimp	10.0	12.2

and *Balanus* spp. were identified. The shrimp remains never appeared to have any muscular tissue attached to them so perhaps, molted exoskeletons were taken. Polychaetes were occasionally taken; however, Capitellidae and Spionidae were the only families identified. Pink shrimp from the outer shelf of Kodiak Island most frequently contained remains of crustaceans, bivalves, foraminiferans, and fishes. Few diatoms were found in shrimp from the outer shelf stations. The bivalves taken included *Nucula, Yoldia* and *Axinopsida*. Fish remains included bones, vertebrae, and scales.

Pycnopodia helianthoides (Sunflower Sea Star)

In four months of sampling (May, June, August and November 1978) sunflower sea stars in Izhut Bay, 199 were examined for food and 148 (74%) contained food (Table LXXIII). The sea stars were sampled at a variety of stations. Molluscs dominated the stomach contents in all months. The snails *Oenopota* sp. and *Solariella* sp. were consistently taken as food. Dominant clams included *Nuculana fossa, Psephidia lordi* and *Spisula polynyma.*

Pycnopodia examined in May and June by SCUBA in shallow bays adjacent to the city of Kodiak, were observed feeding on the cockle *Clinocardium nuttallii*, the clams *Mya arenaria, Protothaca staminea*, and *Saxidomus gigantea*, and barnacles.

Gadus macrocephalus (Pacific Cod) (Table LXXIV)

Izhut Bay (Figure 1)

A total of 18 Pacific cod were examined in mid-May 1978. Seventeen fish contained food; only four taxa were present. The most frequently occurring prey was *Pandalus borealis* (83.3%). Unidentified fishes (22.2%) and *Chionoecetes bairdi* (16.7%) were less frequently found. Cod were taken from Stations 2 and 3.

Kodiak Shelf - June-July 1978 (Figure 5)

Pacific cod stomachs were dominated by crustaceans. Ninety-six percent of the 190 cod examined were feeding, and 41 prey taxa were identified. The

TABLE LXXIII

STOMACH CONTENTS OF THE SUN FLOWER SEA STAR (*PYCNOPODIA HELIANTHOIDES*) FROM IZHUT BAY, AFOGNAK ISLAND REGION, 1978

(N) = Number of Stomachs

	Percent Frequency of Occurrence Based on	
Stomach Contents	Total Stomachs	Stomachs w/food
4-19 May 1978	N = 105	N = 91
Oenopota sp. (snail) (34)	32.4	37.4
Solariella sp. (snail) (23)	21.9	25.3
Nuculana fossa (Fossa nut clam) (15)	14.3	16.5
Empty (14)	13.3	-
Psephidia lordi (Lord's dwarf venus) (12)	11.4	13.2
Spisula polynyma (surf clam) (9)	8.6	9.0
Balanus spp. (barnacle) (9)	8.6	9.0
Mitrella gouldi ((snail) (6)	5.7	6.6
Chionoecetes bairdi (snow crab) (6)	5.7	6.6
Clinocardium ciliatum (Iceland cockle) (5)	4.8	5.5
Natica clausa (moon shell) (4)	3.8	4.4
Amphipoda (sand flea) (3)	2.9	3.3
Crangonidae (gray shrimp) (3)	2.9	3.3
Parastichopus sp. (sea cucumber) (3)	2.9	3.3
Serripes groenlandicus (Greenland cockle) (3)	2.9	3.3
Polychaeta (segmented worm) (2)	1.9	2.2
Macoma sp. (bivalve) (2)	1.9	2.2
Mya priapus (bivalve) (2)	1.9	2.2
Mya sp. (bivalve) (2)	1.9	2.2
Musculus discors (discord Musculus) (2)	1.9	2.2
Nucula tenuis (soft nut clam) (2)	1.9	2.2
Pandora sp. (bivalve) (2)	1.9	2.2
Nucella lamellosa (frilled dogwinkle) (2)	1.9	2.2
Gastropoda (snail) (2)	1.9	2.2
Cancer sp. (crab) (2)	1.9	2.2
Pagurus sp. (hermit crab) (2)	1.9	2.2
Elassochirus tenuimanus (hermit crab) (2)	1.9	2.2
Siliqua sp. (razor clam) (1)	1.0	1.1
Tellina nuculoides (salmon Tellin) (1)	1.0	1.1
Tellinidae (bivalve) (1)	1.0	1.1
Macoma lipara (bivalve) (1)	1.0	1.1
Macoma moesta (doleful Macoma) (1)	1.0	1.1
Pandora grandis (bivalve) (1)	1.0	1.1
Musculus sp. (bivalve) (1)	1.0	1.1
Thyasira flexuosa (flexuose cleft clam) (1)	1.0	1.1
Clinocardium sp. (cockle) (1)	1.0	1.1
Liocyma sp. (bivalve) (1)	1.0	1.1
Mya truncata (soft shell clam) (1)	1.0	1.1

TABLE LXXIII

CONTINUED

	Percent Frequency of Occurrence Based on	
Stomach Contents	Total Stomachs	Stomachs w/food
Pelecypoda (bivalves) (1)	1.0	1.1
Admete cauthouyi (common northern admete) (1)	1.0	1.1
Suavodrillia sp. (snail) (1)	1.0	1.1
Buccinum plectrum (Plectrum buccinum) (1)	1.0	1.1
Pagurus ochotensis (hermit crab) (1)	1.0	1.1
Balanus rostratus (barnacle) (1)	1.0	1.1
Oregonia gracilis (decorator crab) (1)	1.0	1.1
Bankia setacea (shipworm) (1)	1.0	1.1
Sand (1)	1.0	1.1
8-25 June 1978	N = 44	N = 15
Empty (29)	65.9	-
Solariella sp. (snail) (4)	9.1	26.7
Echinarachnius parma (sand dollar) (3)	6.8	20.0
Cucumaria sp. (sea cucumber) (2)	4.5	13.3
Oenopota sp. (snail) (2)	4.5	13.3
Spisula polynyma (surf clam) (2)	4.5	13.3
Macoma sp. (bivalve) (2)	4.5	13.3
Psephidia lordi (Lord's dwarf venus) (2)	4.5	13.3
Siliqua sp. (razor clam) (1)	2.3	6.7
Pandora sp. (bivalve) (1)	2.3	6.7
Admete couthouyi (common northern admete) (1)	2.3	6.7
Natica clausa (moon shell) (1)	2.3	6.7
Scyphozoa (jellyfish) (1)	2.3	6.7
Pleuronectidae (flatfishes) (1)	2.3	6.7
Fish (1)	2.3	6.7
8-23 August 1978	N = 14	N = 12
Balanus sp. (barnacle) (4)	28.6	33.3
Psephidia lordi (Lord's dwarf venus) (3)	21.4	25.0
Spisula polynyma (surf clam) (3)	21.4	25.0
Mya sp. (bivalve) (3)	21.4	25.0
Solariella sp. (snail) (3)	21.4	25.0
Oenopota sp. (snail) (3)	21.4	25.0
Pagurus sp. (hermit crab) (3)	21.4	25.0
Ctenophora (comb jelly) (3)	21.4	25.0
Empty (2)	14.3	-
Polychaeta (segmented worm) (1)	7.1	8.3
Macoma sp. (bivalve) (1)	7.1	8.3
Musculus sp. (bivalve) (1)	7.1	8.3
Polinices sp. (moon shell) (1)	7.1	8.3

TABLE LXXIII

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs w/food
4-17 November 1978	N = 36	N = 30
Oenopota sp. (snail) (17)	47.2	56.7
Solariella sp. (snail) (17)	47.2	56.7
Nuculana fossa (Fossa nut clam) (11)	30.6	36.7
Psephidia lordi (Lord's dwarf venus) (7)	19.4	23.3
Empty (6)	16.7	-
Spisula polynyma (surf clam) (3)	8.3	10.0
Glycymeris subobsoleta (west coast buttersweet) (3)	8.3	10.0
Natica clausa (moon shell) (3)	8.3	10.0
Chionoecetes bairdi (snow crab) (3)	8.3	10.0
Cnidaria (jellyfish, sea anemones, corals) (2)	5.6	6.7
Cylichna sp. (snail) (2)	5.6	6.7
Macoma sp. (bivalve) (2)	5.6	6.7
Polychaeta (segmented worm) (1)	2.8	3.3
Cistenides sp. (polychaeta worm) (1)	2.8	3.3
Cyclocardia sp. (bivalve) (1)	2.8	3.3
Lyonsia sp. (bivalve) (1)	2.8	3.3
Veneridae (bivalves) (1)	2.8	3.3
Mitrella sp. (snail) (1)	2.8	3.3
Naticidae (snails) (1)	2.8	3.3
Turritellidae (snails) (1)	2.8	3.3
Turridae (snails) (1)	2.8	3.3
Balanus sp. (barnacle) (1)	2.8	3.3
Crangon sp. (gray shrimp) (1)	2.8	3.3
Cancer sp. (crab) (1)	2.8	3.3
Pugettia gracilis (kelp crab) (1)	2.8	3.3
Pagurus sp. (hermit crab) (1)	2.8	3.3
Pagurus ochotensis (hermit crab) (1)	2.8	3.3
Echinodermata (sea star) (1)	2.8	3.3
Trichodon trichodon (Pacific swordfish) (1)	2.8	3.3
Fish (1)	2.8	3.3

most frequent species were *Chionoecetes bairdi* (32.1%), *Pandalus borealis* (26.8%), Euphausiacea (23.7%), fishes (18.4%), crangonid shrimps (14.2%), the pea crab *Pinnixa occidentalis* (10%), and walleye pollock *Theragra chalcogramma* (10%). All cod came from Stations 1, 3, 4, 5, 6, 9, 10, 11, 13, 22 and 44. The highest frequency of *C. bairdi* in cod stomachs came from Stations 4, 9 and 11. *Pandalus borealis* as a food item, was mainly taken at Stations 11 and 13.

Kiliuda Bay - August 1978 (Figure 2)

Twenty Pacific cod were examined during the August 1978 sampling. Stomach contents contained only two taxa. All were feeding on *Pandalus borealis* and four were feeding on *P. hypsinotus*. All 20 fish came from Station 5.

Kodiak Shelf - February 1979 (Figure 5)

Fifty-five Pacific cod were examined during this sampling period, and 45 contained food. The most frequently consumed prey in all cod examined was unidentified fishes (23.6% frequency of occurrence), snow crab (*Chionoecetes bairdi*; 20.0%), pink shrimp (*Pandalus borealis*; 18.2%), and crangonid shrimp (18.2%).

Hemilepidotus jordani (Yellow Irish Lord) (Table LXXIV)

Kodiak Shelf - March 1978 (Figure 4)

Thirty-nine yellow Irish lord were examined during the March 1978 cruise. A total of 17 prey taxa were found in 36 feeding fish. Leading prey, in terms of frequency of occurrence, were *Chionoecetes bairdi* (48.7%), the hermit crab *Pagurus ochotensis* (20.5%), shrimp (12.8%), and amphipods (10.3%). Polychaeteous annelids and fishes occurred in 15.4% of the fish. Yellow Irish lord were examined from Stations 1, 2, and 5.

Kodiak Shelf - June-July 1978 (Figure 5)

Yellow Irish lord examined from the June-July cruise was dominated by polychaetes (19.6% frequency of occurrence), *Pinnixa occidentalis* (15.9%),

TABLE LXXIV

STOMACH CONTENTS OF SELECTED FISHES FROM THE KODIAK ISLAND REGION, 1978-79

(N) = Number of Stomachs

Stomach Contents	Percent Frequency of Occurrence Based on	
	Total Stomachs	Stomachs w/food
GADUS MACROCEPHALUS (Pacific cod)		
Izhut Bay - 11-14 May 1978	N = 18	N = 17
Pandalus borealis (pink shrimp) (15)	83.3	88.2
Fishes (4)	22.2	23.5
Chionoecetes bairdi (snow crab) (3)	16.7	17.6
Elassochirus gilli (hermit crab) (1)	5.6	5.9
Empty (1)	5.6	-
Kodiak Shelf - 19 June-9 July 1978	N = 190	N = 182
Chionoecetes bairdi (snow crab) (61)	32.1	33.5
Pandalus borealis (pink shrimp) (51)	26.8	28.0
Euphausiacea (krill) (45)	23.7	24.7
Fishes (35)	18.4	19.2
Crangonidae (gray shrimp) (27)	14.2	14.8
Pinnixa occidentalis (pea crab) (19)	10.0	14.4
Theragra chalcogramma (walleye pollock) (19)	10.0	14.4
Octopus sp. (11)	5.8	6.0
Ammodytes hexapterus (Pacific sand lance) (11)	5.8	6.0
Lumpenus sagitta (Pacific snake prickleback) (10)	5.3	5.5
Polychaeta (segmented worm) (9)	4.7	4.9
Empty (8)	4.2	-
Pelecypoda (bivalves) (6)	3.2	3.3
Hyas lyratus (lyre crab) (5)	2.8	2.7
Zoarcidae (eelpouts) (4)	2.1	2.2
Unid. material (4)	2.1	2.2
Spisula polynyma (surf clam) (3)	1.6	1.6
Paralithodes camtschatica (red king crab) (3)	1.6	1.6
Crabs (3)	1.6	1.6
Pleuronectidae (flatfishes) (3)	1.6	1.6
Aphrodita sp. (polychaeta worm) (2)	1.1	1.1
Nematoda (round worms) (2)	1.1	1.1
Nuculana fossa (Fossa nut clam) (2)	1.1	1.1
Gastropoda (snail) (2)	1.1	1.1
Hippolytidae (shrimp) (2)	1.1	1.1
Pagurus sp. (hermit crab) (2)	1.1	1.1
Elassochirus gilli (hermit crab) (2)	1.1	1.1
Pandalopsis dispar (side-stripe shrimp) (2)	1.1	1.1

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs w/food
Hippoglossoides elassodon (flathead sole) (2)	1.1	1.1
Tellina nuculoides (salmon Tellin) (1)	0.5	0.5
Serripes groenlandicus (Greenland cockle) (1)	0.5	0.5
Shrimp (1)	0.5	0.5
Paguridae (hermit crabs) (1)	0.5	0.5
Elassochirus tenuimanus (hermit crab) (1)	0.5	0.5
Pagurus kennerlyi (hermit crab) (1)	0.5	0.5
Balanus sp. (barnacle) (1)	0.5	0.5
Ophiuroidea (brittle stars) (1)	0.5	0.5
Dasycottus setiger (spinyhead sculpin) (1)	0.5	0.5
Cottidae (sculpins) (1)	0.5	0.5
Trichodon trichodon (Pacific sandfish) (1)	0.5	0.5
Lumpenella longirostris (longsnout prickleback) (1)	0.5	0.5
Lyconectes aleutensis (dwarf wrymouth) (1)	0.5	0.5
Rock (1)	0.5	0.5
Kiliuda Bay - 8-23 August 1978	N = 20	N = 20
Pandalus borealis (pink shrimp) (20)	100.0	100.0
Pandalus hypsinotus (coon-stripe shrimp) (4)	20.0	20.0
Kodiak Shelf - 13-24 February 1979	N = 55	N = 45
Pisces (13)	23.6	28.9
Chionoecetes bairdi (snow crab) (11)	20.0	24.4
Pandalus borealis (pink shrimp) (10)	18.2	22.2
Crangonidae (gray shrimp) (10)	18.2	22.2
Empty (10)	18.2	-
Shrimp (6)	10.9	13.3
Theragra chalcogramma (walleye pollock) (5)	9.1	11.1
Polychaeta (segmented worm) (3)	5.5	6.7
Trichotropis sp. (2)	3.6	4.4
Octapoda (2)	3.6	4.4
Pinnixa sp. (pea crab) (2)	3.6	4.4
Stichaeidae (pricklebacks) (2)	3.6	4.4
Ammodytes hexapterus (Pacific sand lance) (2)	3.6	4.4
Osmeridae (smelts) (2)	3.6	4.4
Plant (1)	1.8	2.2
Hydrozoa (1)	1.8	2.2
Cyclocardia sp. (cockle) (1)	1.8	2.2
Yoldia sp. (bivalve) (1)	1.8	2.2

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs w/food
Colus sp. (snail) (1)	1.8	2.2
Gastropoda (snails) (1)	1.8	2.2
Crustacea (1)	1.8	2.2
Crab (1)	1.8	2.2
Euphausiacea (krill) (1)	1.8	2.2
Pagurus aleuticus (Hermit crab) (1)	1.8	2.2
Echiuroidea (spoon worm) (1)	1.8	2.2
Gadidae (cods) (1)	1.8	2.2
Zoarchidae (eelpouts) (1)	1.8	2.2
Pleuronectidae (flatfish) (1)	1.8	2.2
Lyconectes aleutensis (dwarf wrymouth)	1.8	2.2
Unid. material (1)	1.8	2.2
HEMILEPIDOTUS JORDANI (yellow Irish lord)		
21-24 March 1978	N = 39	N = 36
Chionoecetes bairdi (snow crab) (19)	48.7	52.8
Pagurus ochotensis (hermit crab) (8)	20.5	22.2
Polychaeta (segmented worm) (6)	15.4	16.7
Fishes (6)	15.4	16.7
Shrimps (5)	12.8	13.9
Amphipoda (sand flea) (4)	10.3	11.1
Octopus sp. (3)	7.7	8.3
Empty (3)	7.7	-
Crangonidae (gray shrimp) (2)	5.1	5.6
Cylichna sp. (snail) (1)	2.6	2.8
Gastropoda (snail) (1)	2.6	2.8
Neptunea sp. (snail) (1)	2.6	2.8
Pelecypoda (bivalve) (1)	2.6	2.8
Hermit crab (1)	2.6	2.8
Paralithodes camtschatica (red king crab) (1)	2.6	2.8
Ophiuroidea (brittle star) (1)	2.6	2.8
Lycodes brevipes (shortfin eelpout) (1)	2.6	2.8
Cyclopteridae (1)	2.6	2.8
Kodiak Shelf - 19 June-9 July 1978	N = 189	N = 152
Polychaeta (segmented worms) (37)	19.6	24.3
Empty (37)	16.9	-
Pinnixa occidentalis (pea crab) (30)	15.9	19.7

TABLE LXXIV

CONTINUED

	Percent Frequency of Occurrence Based on	
Stomach Contents	Total Stomachs	Stomachs w/food
Chionoecetes bairdi (snow crab) (20)	10.6	13.2
Euphausiacea (krill) (18)	9.5	11.8
Unid. material (15)	7.9	9.9
Pandalus borealis (pink shrimp) (14)	7.4	9.2
Fishes (14)	7.4	9.2
Pagurus aleuticus (hermit crab) (12)	6.3	7.9
Elassochirus tenuimanus (hermit crab) (11)	5.8	7.2
Paguridae (hermit crab) (7)	4.6	4.6
Unid. pelecypods (7)	3.7	4.6
Yoldia myalis (comb Yoldia) (6)	3.2	3.9
Hyas lyratus (lyre crab) (6)	3.2	3.9
Ophiuroidea (brittle stars) (6)	3.2	3.9
Gastropoda (snail) (5)	2.6	3.3
Echiurus echiurus (the fat innkeeper)	2.6	3.3
Lumpenus sagitta (Pacific snake prickleback) (4)	2.1	2.6
Macoma moesta (doleful Macoma) (3)	1.6	2.0
Amphipoda (sand flea) (3)	1.6	2.0
Octopus sp. (2)	1.1	1.3
Oregonia gracilis (decorator crab) (2)	1.1	1.3
Labidochirus splendescens (hermit crab) (2)	1.1	1.3
Crabs (2)	1.1	1.3
Pectinidae (scallop) (1)	0.5	0.7
Nuculana fossa (Fossa nut clam) (1)	0.5	0.7
Buccinum plectrum (Plectrum Buccinum) (1)	0.5	0.7
Crangonidae (gray shrimp) (1)	0.5	0.7
Shrimp (1)	0.5	0.7
Cancer sp. (crab) (1)	0.5	0.7
Lycodes brevipes (shortfin eelpout) (1)	0.5	0.7
Kodiak Shelf - 13-24 February 1979	N = 90	N = 63
Empty (27)	30.0	-
Chionoecetes bairdi (snow crab) (22)	24.4	34.9
Pisces (fishes) (13)	14.4	20.6
Pinnixa occidentalis (pea crab) (8)	8.9	12.7
Euphausiacea (krill) (7)	7.8	11.1
Polychaeta (segmented worm) (6)	6.7	9.5
Pandalus borealis (pink shrimp) (6)	6.7	9.5
Macoma sp. (bivalve) (4)	4.4	6.3
Shrimp (3)	3.3	4.8
Echiurus echiurus (spoon worm) (3)	3.3	4.8
Ammodytes hexapterus (Pacific sand lance) (3)	3.3	4.8

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on	
	Total Stomachs	Stomachs w/food
Yoldia sp. (bivalve) (2)	2.2	3.2
Pelecypoda (bivalve) (2)	2.2	3.2
Crustacea (2)	2.2	3.2
Pherusa plumosa (segmented worm) (1)	1.1	1.6
Nudibranch (1)	1.1	1.6
Octopoda (1)	1.1	1.6
Gastropoda (snails) (1)	1.1	1.6
Gammaridae (sand fleas) (1)	1.1	1.6
Pagurus aleuticus (1)	1.1	1.6
Triglops sp. (sculpin) (1)	1.1	1.6
Sediment (1)	1.1	1.6
Eggs (1)	1.1	1.6
Unid. material (1)	1.1	1.6
MYOXOCEPHALUS spp. (Sculpins)		
Izhut Bay - 4-19 May 1978	N = 19	N = 15
Pandalus borealis (pink shrimp) (10	52.6	66.7
Chionoecetes bairdi (snow crab) (6)	31.6	40.0
Empty (4)	21.1	-
Fishes (2)	10.5	13.3
Nuculana fossa (Fossa nut clam) (1)	5.3	6.7
Lumpenus sagitta (Pacific snake prickleback (1)	5.3	6.7
Kodiak Shelf - 19 June-9 July 1978	N = 72	N = 47
Fishes (26)	36.1	55.3
Empty (25)	34.7	-
Pandalus borealis (pink shrimp) (9)	12.5	19.1
Lycodes brevipes (shortfin eelpout) (5)	6.9	10.6
Octopus sp. (3)	4.2	6.4
Crangonidae (gray shrimp) (3)	4.2	6.4
Chionoecetes bairdi (snow crab) (3)	4.2	6.4
Hyas lyratus (lyre crab) (3)	4.2	6.4
Mallotus villosus (capelin) (3)	4.2	6.4
Lumpenus sagitta (Pacific snake prickleback) (3)	4.2	6.4
Pelecypoda (bivalves) (2)	2.8	4.3
Echinarachnius parma (sand dollar) (2)	2.8	4.3
Pleuronectidae (flatfishes) (2)	2.8	4.3
Cottidae (sculpins) (2)	2.8	4.3
Nuculana fossa (Fossa nut clam) (1)	1.4	2.1

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on	
	Total Stomachs	Stomachs w/food
Pandalopsis dispar (side-stripe shrimp) (1)	1.4	2.1
Shrimp (1)	1.4	2.1
Unid. material (1)	1.4	2.1
Theragra chalcogramma (walleye pollock) (1)	1.4	2.1
Kodiak Shelf - 13-24 February 1979	N = 12	N = 11
Chionoecetes bairdi (snow crab) (8)	66.7	72.7
Theragra chalcogramma (walleye pollock) (3)	25.0	27.3
Pisces (fishes) (3)	25.0	27.3
Pandalus goniurus (humpy shrimp) (2)	16.7	18.2
Octopoda (2)	16.7	18.2
Hippolytidae (shrimp) (1)	8.3	9.1
Eucalus sp. (shrimp) (1)	8.3	9.1
Pandalus hypsinotus (coon-stripe shrimp) (1)	8.3	9.1
Shrimp (1)	8.3	9.1
Rock (1)	8.3	9.1
Empty (1)	8.3	-
HIPPOGLOSSOIDES ELASSODON		
Kodiak Shelf - 19 June-19 July 1978	N = 156	N = 118
Pandalus borealis (pink shrimp) (46)	29.5	39.0
Empty (38)	24.4	-
Euphausiacea (krill) (21)	13.5	17.8
Chionoecetes bairdi (snow crab) (13)	8.3	11.0
Macoma moesta (doleful macoma) (10)	6.4	8.5
Ophiura sarsi (brittle star) (9)	5.8	7.6
Ophiuridae (brittle star) (6)	3.8	5.1
Unid. material (5)	3.2	4.2
Shrimps (4)	2.6	3.4
Tube-dwelling polychaetes (3)	1.9	2.5
Pelecypoda (bivalves) (3)	1.9	2.5
Clinocardium ciliatum (Iceland cockle) (3)	1.9	2.5
Actiniidae (sea anemone) (3)	1.9	2.5
Pagurus aleuticus (hermit crab) (3)	1.9	2.5
Polychaeta (segmented worm) (2)	1.3	1.7
Nuculana fossa (Fossa nut clam) (2)	1.3	1.7
Crangonidae (gray shrimp) (2)	1.3	1.7
Pinnotheridae (pea crabs) (2)	1.3	1.7
Sand (2)	1.3	1.7

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs w/food
Yoldia scissurata (bivalve) (1)	0.6	0.8
Cardiidae (bivalves) (1)	0.6	0.8
Axinopsida serricata (silky Axinopsis) (1)	0.6	0.8
Gastropoda (1)	0.6	0.8
Pteropoda (1)	0.6	0.8
Isopoda (1)	0.6	0.8
Labidochirus splendescens (hermit crab) (1)	0.6	0.8
Spisula polynyma (surf clam) (1)	0.6	0.8
Lycodes brevipes (shortfin eelpout) (1)	0.6	0.8
Clupea harengus pallasi (Pacific herring) (1)	0.6	0.8
Kodiak Shelf - 13-24 February 1979	N = 90	N = 49
Empty (41)	45.6	-
Pandalus borealis (pink shrimp) (18)	20.0	36.7
Euphausiacea (krill) (10)	11.1	20.7
Shrimp (5)	5.6	10.2
Macoma moesta (4)	4.4	8.2
Crangonidae (gray shrimp) (3)	3.3	6.1
Chionoecetes bairdi (snow crab) (3)	3.3	6.1
Polychaeta (segmented worms) (2)	2.2	4.1
Pinnixa sp. (pea crab) (2)	2.2	4.1
Unid. material (2)	2.2	4.1
Nuculana fossa (Fossa nut shell) (1)	1.1	2.0
Yoldia amygdalea (bivalve) (1)	1.1	2.0
Theragra chalcogramma (walleye pollock) (1)	1.1	2.0
Stichaeidae (pricklebacks) (1)	1.1	2.0
Hippoglossoides elassodon (flathead sole) (1)	1.1	2.0
Pisces (fishes) (1)	1.1	2.0
LEPIDOPSETTA BILINEATA (Rock sole)		
Izhut Bay - 4-19 May 1978	N = 23	N = 16
Polychaeta (segmented worm) (12)	52.2	75.0
Empty (7)	30.4	-
Algae (2)	8.7	12.5
Pandalus borealis (pink shrimp (1)	4.3	6.3
Shrimps (1)	4.3	6.3

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs w/food
Kodiak Shelf - 19 June-9 July 1978	N = 94	N = 84
Yoldia myalis (comb Yoldia) (29)	30.9	34.5
Polychaeta (segmented worm) (27)	28.7	32.1
Ophiuridae (brittle stars) (16)	17.0	19.0
Cucumaria sp. (sea cucumber) (11)	11.7	13.1
Echinarachnius parma (sand dollar) (11)	11.7	13.1
Empty (10)	10.6	-
Tellina nuculoides (salmon Tellin) (8)	8.5	9.5
Spisula polynyma (surf clam) (7)	7.4	8.3
Amphipoda (sand flea) (7)	7.4	8.3
Cancer sp. (crab) (6)	6.4	7.1
Clinocardium californiense (bivalve) (6)	6.4	7.1
Hyas lyratus (lyre crab) (6)	6.4	7.1
Pelecypoda (bivalves) (5)	5.3	6.0
Fishes (5)	5.3	6.0
Sipunculida (peanut worm) (4)	4.3	4.8
Nuculana fossa (Fossa nut clam) (4)	4.3	4.8
Cistenides sp. (polychaeta worm) (4)	4.3	4.8
Chlamys rubida (Hind's scallop) (4)	4.3	4.8
Chionoecetes bairdi (snow crab) (4)	4.3	4.8
Travisia forbesii (polychaeta worm) (3)	3.2	3.6
Crangonidae (gray shrimp) (3)	3.2	3.6
Shrimps (3)	3.2	3.6
Strongylocentrotus sp. (sea urchin) (3)	3.2	3.6
Ammodytes hexapterus (Pacific sand lance) (3)	3.2	3.6
Unid. material (3)	3.2	3.6
Propeamussium alaskense (scallop) (2)	2.1	2.4
Macoma moesta (doleful Macoma) (2)	2.1	2.4
Cardiidae (bivalves) (2)	2.1	2.4
Musculus sp. (bivalve) (1)	1.1	1.2
Laqueus californianus (lamp shell) (1)	1.1	1.2
Balanus sp. (barnacle) (1)	1.1	1.2
Elassochirus tenuimanus (hermit crab) (1)	1.1	1.2
Elassochirus gilli (hermit crab) (1)	1.1	1.2
Oregonia gracilis (decorator crab) (1)	1.1	1.2
Ctenodiscus crispatus (mud star) (1)	1.1	1.2
Ophiura sarsi (brittle star) (1)	1.1	1.2
Stichaeidae (pricklebacks) (1)	1.1	1.2
Golfingia vulgaris (peanut worm) (1)	1.1	1.2
Diamphiodia craterodmeta (brittle star) (1)	1.1	1.2
Ophiopenia disacantha (brittle star) (1)	1.1	1.2
Serripes groenlandicus (Greenland cockle) (1)	1.1	1.2

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Stomachs w/food
Spisula polynyma (surf clam) (1)	1.1	1.2
Maldanidae (bamboo worm) (1)	1.1	1.2
Kodiak Shelf - 13-24 February 1979	N = 70	N = 31
Empty (39)	55.7	-
Polychaeta (segmented worms) (18)	25.7	58.1
Yoldia myalis (bivalve) (6)	8.6	19.4
Ophiuroidea (brittle stars) (6)	8.6	19.4
Macoma moesta (bivalve) (3)	4.3	9.7
Shrimp (3)	4.3	9.7
Ophiura sarsi (brittle star) (3)	4.3	9.7
Unid. material (3)	4.3	9.7
Pelecypoda (bivalves) (2)	2.9	6.5
Serripes groenlandicus (clam) (2)	2.9	6.5
Amphipoda (sand fleas) (2)	2.9	6.5
Hydrozoa (1)	1.4	3.2
Travisia forbesii (segmented worm) (1)	1.4	3.2
Pherusa plumosa (segmented worm) (1)	1.4	3.2
Nuculana fossa (Fossa nut shell) (1)	1.4	3.2
Crustacea (1)	1.4	3.2
Thoracica (barnacles) (1)	1.4	3.2
Molpadia sp. (sea cucumber) (1)	1.4	3.2
Echiurus echiurus (spoon worm) (1)	1.4	3.2
Sediment (1)	1.4	3.2
ATHERESTHES STOMIAS (arrowtooth flounder)		
Kodiak Shelf - 19 June-9 July 1978	N = 18	N = 9
Empty (9)	50.0	-
Theragra chalcogramma (walleye pollock) (5)	27.8	55.6
Ammodytes hexapterus (Pacific sand lance) (2)	11.1	22.2
Fish (1)	5.6	11.1
Unid. material (1)	5.6	11.1
PLEUROGRAMMUS MONOPTERIGIUS (Atka mackerel)		
Kodiak Shelf - 19 June-9 July 1978	N = 20	N = 20
Ammodytes hexapterus (Pacific sand lance) (17)	85.0	85.0
Euphausiacea (krill) (6)	30.0	30.0
Gastropoda (1)	5.0	5.0

TABLE LXXIV

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs w/food
ANAPLOPOMA FIMBRIA (sablefish)		
Kodiak Shelf - 19 June-9 July 1978	N = 31	N = 31
Ammodytes hexapterus (Pacific sand lance) (31)	100.0	100.0
Euphausiacea (krill) (2)	6.5	6.5
THERAGRA CHALCOGRAMMA (walleye pollock)		
Kiliuda Bay - 8-23 August 1978	N = 20	N = 20
Pandalus borealis (pink shrimp) (20)	100.0	100.0
Pandalus hypsinotus (coon-stripe shrimp) (4)	20.0	20.0
LIMANDA ASPERA (yellowfin sole)		
Kodiak Shelf - 13-24 February 1979	N = 50	N = 23
Empty (27)	54.0	-
Echiurus echiurus (spoon worm) (10)	20.0	43.5
Pinnixa occidentalis (pea crab) (9)	18.0	39.1
Pandalus borealis (pink shrimp) (9)	18.0	39.1
Macoma sp. (bivalve) (4)	8.0	17.4
Polychaeta (segmented worm) (3)	6.0	13.0
Yoldia amygdalea (bivalve) (3)	6.0	13.0
Hirudinea (leech) (1)	2.0	4.3
Argis sp. (gray shrimp) (1)	2.0	4.3
Crustacean (1)	2.0	4.3
Pisces (fish) (1)	2.0	4.3
Unid. material (1)	2.0	4.3
ISOPSETTA ISOLEPIS (butter sole)		
Kodiak Shelf - 13-24 February 1979	N = 20	N = 6
Empty (14)	70.0	-
Polychaeta (segmented worm) (2)	10.0	66.6
Macoma sp. (bivalve) (1)	5.0	33.3
Pandalus borealis (pink shrimp) (1)	5.0	33.3
Shrimp (1)	5.0	33.3
Chionoecetes bairdi (snow crab) (1)	5.0	33.3
Pisces (fish) (1)	5.0	33.3
Unid. material (1)	5.0	33.3

and *Chionoecetes bairdi* (10.6%). Thirty different prey taxa were found in 152 feeding fish. All fish came from Stations 3, 4, 5, 6, 9, 10, 11, 12, 13, 22, and 44. The highest frequency of polychaetes in yellow Irish lords came from Stations 4 and 44. *Pinnixa* was mainly taken at Station 12.

Kodiak Shelf - February 1979 (Figure 5)

Among the 90 yellow Irish lord that were examined, 27 had empty stomachs. Dominant prey in terms of frequency of occurrence in the 90 fish were snow crab (24.4%) and unidentified fishes (14.4%). Pea crab (*Pinnixa occidentalis*), krill, polychaetes, and pink shrimp occurred at between 5-10% frequency of occurrence.

Myoxocephalus sp. (Sculpins) (Table LXXIV)

Izhut Bay - May 1978 (Figure 1)

Sculpins examined (19) in May 1978 mainly contained *Pandalus borealis* (52.6%) and *Chionoecetes bairdi* (31.6%). Sculpins were examined for food contents from Stations 2 and 3.

Kodiak Shelf - June-July 1978 (Figure 5)

Sculpins examined (72) on the June-July 1978 cruise contained 19 different prey taxa. Only 47 (65%) contained food. Dominant food items were unidentified fishes (36.1%) and *Pandalus borealis* (12.5%). Sculpins came from Stations 1, 3, 5, 6, 8, 10, 11, and 22.

Kodiak Shelf - February 1979 (Figure 5)

Only 12 sculpins of the genera *Myoxocephalus* were examined during February 1979; 11 stomachs contained food. The most important prey were snow crab (66.7% occurrence), walleye pollock (*Theragra chalcogramma*; 25%), and unidentified fishes (25%).

Hippoglossoides elassodon (Flathead Sole) (Table LXXIV)

Kodiak Shelf - June-July 1978 (Figure 5)

One hundred and fifty-six flathead sole stomachs were examined during June-July 1978. A total of 118 (76%) were feeding. Although 28 prey were identified, the only dominant food items were *Pandalus borealis* (29.5%) and Euphausiacea (13.5%). Flathead sole came from nine stations: 3, 4, 5, 6, 9, 11, 13, 14, and 44. Pink shrimp dominated the prey at Stations 11, 13, and 14.

Kodiak Shelf - February 1979 (Figure 5)

Ninety flathead sole were examined during February 1979; 45.6% had empty stomachs. The most frequently consumed food in 90 fish was pink shrimp (20%), and krill (11.1%).

Lepidopsetta bilineata (Rock Sole) (Table LXXIV)

Izhut Bay - May 1978 (Figure 1)

The 23 rock sole examined in Izhut Bay in May mainly contained polychaetes (52%). Two fish contained algal material and two fish contained shrimp. Thirty percent of the stomachs were empty.

Kodiak Shelf - June-July 1978 (Figure 5)

Rock sole examined in June-July 1978 contained a wide variety of prey items. Eighty-nine percent (84/94) were feeding. Forty-two different prey taxa were identified. Leading prey, in terms of frequency of occurrence, were the clam *Yoldia myalis* (30.9%), Polychaeta (28.7%), brittle stars-Ophiuridae (17%), sea cucumbers-*Cucumaria* sp. (11.7%), and the sand dollar, *Echinarachnius parma* (11.7%). Rock sole examined came from Stations 1, 2, 3, 6, 22, and 44. Among the three stations where *Yoldia* was taken as food, Stations 2 and 3 were most important.

Kodiak Shelf - February 1979 (Figure 5)

More than 55% of the 70 rock sole examined in February 1979 had empty stomachs. The most important prey among feeding rock sole were polychaetes (58.1% occurrence). A variety of other prey were taken.

Pleurogrammus monopterigius (Atka Mackerel) (Table LXXIV)

Kodiak Shelf - June-July 1978 (Figure 5)

All Atka mackerel examined (20) during June-July 1978 came from Station 1. The fish contained mainly *Ammodytes hexapterus* (85%). However, Euphausiacea was taken to a limited degree (30%).

Atheresthes stomias (Arrowtooth Flounder) (Table LXXIV)

Kodiak Shelf - June-July 1978 (Figure 5)

Only nine out of the 18 arrowtooth flounders examined during June-July 1978 contained food. Dominant prey were *Theragra chalcogramma* (27.8%) and the sand lance *Ammodytes hexapterus* (11.1%). Arrowtooth flounders came from Stations 1 and 3.

Anaplopoma fimbria (Sablefish) (Table LXXIV)

Kodiak Shelf - June-July 1978 (Figure 5)

Sablefish examined (31) during June-July 1978 came from Station 2. All were intensively feeding on *Ammodytes hexapterus*. Only 6.5% were feeding on Euphausiacea.

Theragra chalcogramma (Walleye Pollock) (Table LXXIV)

Kiliuda Bay - August 1978 (Figure 2)

Pandalid shrimps were the food of walleye pollock from Kiliuda Bay in August 1978. *Pandalus borealis* was found in all 20 fish examined and *P. hypsinotus* was only found in four stomachs. All pollock were examined from Station 5.

Limanda aspera (Yellowfin Sole) (Table LXXIV)

Kodiak Shelf - February 1979 (Figure 5)

Yellowfin sole stomachs examined in February 1979 also contained little food; 23 out of 50 stomachs contained food. The most frequently found food items among 50 stomachs were the spoon worm (*Echiurus echiurus*; 20%), pea crab (*Pinnixa occidentalis*; 18%), and pink shrimp (18%).

Isopsetta isolepis (Butter Sole) (Table LXXIV)

Kodiak Shelf - February 1979 (Figure 5)

A total of 20 butter sole were examined but only six contained food. No single species dominated. Polychaetes were found in two stomachs and six other food species were each found in only one stomach.

VII. DISCUSSION

TRAWL DATA: DISTRIBUTION-BIOMASS

Since crustaceans, specifically commercially-important species, dominated the epifaunal biomass, the following discussion is mainly directed to those species i.e., *Paralithodes camtschatica, Chionoecetes bairdi,* and *Pandalus borealis.*

Paralithodes camtschatica (King Crab)

A necessary prerequisite for the management of Alaska's crab fisheries is knowledge of the crabs' distribution, abundance, and behavior. King crabs follow yearly migration patterns between deep and shallow waters. Most authors agree that king crabs migrate to shallow waters to spawn during April through June and, after breeding, they gradually migrate back to deeper water (Marukawa, 1933; Rumyantsev, 1945; Vinogradov, 1945; Wallace *et al.*, 1949; Bright *et al.*, 1960; Powell, 1964). The inshore areas of Kodiak Island provide a suitable environment where molting, breeding and feeding activities take place (Wallace *et al.*, 1949; Powel and Nickerson, 1965; Gray and Powell, 1966; Kingsbury and James, 1971; Kingsbury *et al.*, 1974; Feder and Jewett, 1977, present report), although king crabs are known to breed in the offshore ocean environment (McMullen, 1967).

Based on data collected in the present study, Izhut Bay apparently is not an important area for king crabs (Tables III, VII, VIII). The king crab biomass here never exceeded 5.4% of the total invertebrate biomass in any sampling period. The only appreciable quantities came from the entrance to the bay, Area I, Stations 7, 8 and 9 in June and July (Fig. 1).

Unlike Izhut Bay, Kiliuda Bay yielded a preponderance of adult king crabs (Tables III, VII, IX) from a variety of stations. Evidence of the spring migration of crabs into shallow waters was seen in April and June when the crab biomass was highest. Crabs in April were only found in Areas III and IV, Shearwater Bay and Santa Flavia Bay, respectively. The August and November king crab biomass was much lower than spring-summer months, but still not as low as the highest king crab biomass in Izhut Bay in any month. Crabs found in Kiliuda Bay in June through March came from Areas I and IV. The fact that adult crabs were present through early winter suggests the presence of a resident population in Kiliuda Bay.

Benthic trawling has been conducted in two other Kodiak Island bays, Alitak and Ugak Bays (Feder and Jewett, 1977). The king crab biomass from Alitak Bay in June, July, August 1976, and March 1977 was 12.9%, 26.6%, 26.9%, and 68% respectively. These data reflect an influx of adult crabs in March to spawn, and unlike Kiliuda Bay, by June most crabs had migrated from the bay. Changes in the king crab biomasses from Ugak Bay are not as explainable. During the June, July, August, and March sampling the percent of the invertebrate biomass that was king crabs was 17%, 44.3%, 46.7%, and 30.1% respectively (Feder and Jewett, 1977). King crabs in Ugak Bay were mainly juveniles.

King crabs were nearly absent from trawl catches on the Kodiak Shelf in March 1978, and presumably their absence reflects the March-June migration to shallow water for molting and mating activities. In addition to inshore shallows being utilized for breeding, shallow ocean banks are also used for this purpose. McMullen (1967) reported on two offshore king crab breeding locations off Kodiak Island, Marmot Flats and Portlock Bank. These two areas are adjacent to stations sampled in March 1978. It is likely that crabs normally occupying the area adjacent to these ocean banks breed there rather than migrating to nearshore environments.

During June-July 1978 and February 1978, stations where most king crabs were present were located off Alitak Bay at the south end of the island (Figure 5). The composition of king crabs in outer Alitak Bay during June 17-22 1976 (Feder and Jewett, 1977) was similar to the king crab composition found at Stations 7 and 8 of the present study, mainly ovigerous females. Alitak Bay has a past history as a king crab mating ground (Kingsbury and James, 1971; Feder and Jewett, 1977), and has been a major producer of commercial-sized crabs in the Kodiak Island area since 1953 (Gray and Powell, 1966). Outer Alitak Bay was also the site of king crab distribution, abundance, and composition studies conducted by the Alaska Department of Fish and Game during the summer months of 1962 and 1970 (Gray and Powell, 1966; Kingsbury *et al.*, 1974).

Station 9, located in an ADF&G statistical region, sometimes known as the "Horse's Head", was another station where large numbers of adult king crabs were taken (June-July 1978). The "Horse's Head" annually supports one of the largest concentrations of legal size king crabs (≥145 mm carapace length) (ADF&G, umpub. reports). Examination of king crab stomach contents from this region indicates abundant food resources there (see the Food Studies section of this report for further details).

Chionoecetes bairdi (Snow Crab)

Snow crab inhabit the entire Kodiak Shelf to a depth of over 400 m with greatest concentrations found below 130 m (ADF&G, 1976; Donaldson, 1977). Adult snow crabs move into the shallower portions of their habitat in early spring to spawn (Bright, 1967; AEIDC, 1974; ADF&G, 1976). Exact depths and site preferences for spawning in Kodiak are not known; however, 50-130 m depths are used south of the Alaska Peninsula (AEIDC, 1974). Snow crabs typically move into deeper water in the fall. Except for spawning migrations, which are less extensive than king crab migrations, snow crabs (*Chionocetes* spp.) appear to remain in a given location (Watson, 1969).

Data collected during the present study (see *Tables III, VII, VIII*) indicate that snow crabs in Izhut Bay (mostly adult males) were mainly located in Area I, outer Izhut Bay, although the largest catch for April was made at Station 554 in Area III. Area II did not contain any appreciable quantity of crabs in any sampling period. June sampling yielded the largest catch of snow crabs (78.8% of the biomass) and April yielded the lowest catch (3.7%).

Snow crabs in Kiliuda Bay were also found primarily in the outer portion of the bay, Areas I and IV. Both Izhut and Kiliuda Bays, as well as Alitak and Ugak Bays, are producers of snow crabs in commercial quantities (ADF&G, unpub. reports; Feder and Jewett, 1977), and the presence of commercial snow crab gear in the outer portions of Izhut and Kiliuda Bays in February 1979 further substantiate this point.

The only commercial species in any abundance found on the Kodiak Shelf in March 1978 was the snow crab. Although it was a dominant species, it still made up less than 25% of the total invertebrate biomass, and was mainly found at two stations.

Snow crab biomass on the Kodiak Shelf in June-July and February was high at stations located in outer Alitak Bay and off Izhut Bay of Afognak Island (Figure 5). Alaska Department of Fish and Game crab population index studies of Kodiak Island, show moderate catches of snow crabs in the vicinity of Alitak Bay (Donaldson, 1977); however, the area off Izhut Bay was not sampled during these index studies, and so relative abundance data are not available to compare with findings of the present study. Snow crab data from Stations in outer Izhut Bay are parallel with snow crab data from out Izhut Bay sampling.

Pandalus borealis (Pink Shrimp)

Adult pink shrimps inhabit water depths from the intertidal region to beyond the continental shelf (AEIDC, 1974). They appear to concentrate in specific areas around Kodiak, especially in bays and submarine gullies, such as Sitkalidak, Marmot and Afognak Bays, Horse's Head and Marmot Gullies, the Kiliuda Trough and the northeast section of the Shelikof Strait (ADF&G, 1976; Ronholt *et al.*, 1978). Pink shrimps apparently move into shallow bays and around islands to spawn in August and September (Ivanov, 1969). During 1975-76 pink shrimp biomass was estimated at a high 5500-9500 metric tons in the Kiliuda Trough area (ADF&G, 1976).

Pink shrimps were important to the invertebrate biomass in Izhut and Kiliuda Bays as well as Alitak and Ugak Bays (Feder and Jewett, 1977). The largest catches in Izhut Bay came from small bays in May, July, and August i.e., Stations 526 and 527 of Area II and Station 557 of Area III. March 1979 sampling yielded a high biomass of pink shrimp, but unlike the small bays where pink shrimp abounded in other months, this species occurred in the outer portion of the bay (Area I - Station 679). Pink shrimps were not present in Izhut Bay in April, June, and November sampling. We are unable to explain the erratic occurrences of this species in Izhut Bay. However, the high biomasses of pink shrimps in Kiliuda Bay in August and November apparently reflect nearshore migration for spawning.

Pink shrimp from the Kodiak Shelf cruises were most important in June-July 1978 and February 1979, and rarely observed in the March 1978 sampling. It is not surprising that pink shrimps were infrequent from March 1978 stations since, as previously noted, pink shrimps mainly concentrate in bays and submarine gullies.

With the exception of Station 5 (June-July), located in the outer Sitkalidak Gully, pink shrimps from the June-July and February cruises were mainly caught at nearshore stations. The largest concentrations came from outer Izhut Bay. Predators such as Pacific cod and flathead sole were mainly feeding on pink shrimp in this area.

Asteroidea (Sea Stars)

Another epifaunal group of moderate biomass yield, in addition to the commercially-important crustaceans, were the sea stars. Izhut Bay and March 1978 Kodiak Shelf sampling yielded the highest biomasses of this group. Three species were important in Izhut Bay (*Evasterias troschelii*, *Stylasterias forreri* and *Pycnopodia helianthoides*, however, only *Pycnopodia* dominated in all sampling months. The biomass of *Pycnopodia* ranged from a high of 60.7% in April 1978 to a low of 7.8% in March 1979. Stomachs of *Pycnopodia* were examined and the results are included in the Food Studies section of this report.

Stations on the Kodiak Shelf in March 1978 mainly contained the sea star *Dipsacaster borealis*, although *Deplopteraster multipes* was also an important sea star component. *Dipsacaster* accounted for nearly 25% of the epifaunal biomass while *Deplopteraster* only made up 2.2%.

FOOD STUDIES

Paralithodes camtschatica (King Crab)

Food and feeding habits of *Paralithodes camtschatica* have been mainly conducted from the west Kamchatka Shelf and the Okhotsk Sea (Marukawa, 1933; Vinogradov, 1945; Feniuk, 1945: Logvinovich, 1945; Kun and Mikulich, 1954; Kulichkova, 1955; Takeuchi, 1959, 1967 and Tarverdieva, 1976), although, some studies have been carried out in the Sea of Japan (Nakazawa, 1912; Kajita, 1925; Ishii *et al.*, 1929 and Kajita and Nakazawa, 1932) and the southeastern Bering Sea (Kawasaki, 1955; McLaughlin and Hebard, 1961; Chebanov, 1965 and Cunningham, 1969). Feder and Jewett (1977) and Feder and Paul (in press) examined the food of king crabs from Kodiak Island and Cook Inlet, respectively, *via* the frequency of occurrence method. The present study presents quantitative data on food of king crabs from the Kodiak Island region of the Gulf of Alaska.

Analysis of all king crabs in the present study revealed no significant difference in feeding between sexes; however, significant differences were apparent in the quantity of food consumed among feeding crabs from different sampling periods, areas, depths, size groups and crab classes.

The time required for the passage of food through king crab varies with the food item. In a laboratory experiment on king crab (91-95 mm length) Cunningham (1969) noted that fish flesh required about 13 hours for passage, whereas coarse calcareous material required approximately 9 hours longer. Logvinovich (1945) has shown slightly longer periods for larger king crab maintained in the laboratory. Since a large proportion of food items ingested by king crabs in the present study contained hard parts, i.e., bivalves and barnacles, an average time for food passage is estimated at 24 hours. Therefore, consumption of food by adult and sub-adult king crab is only 1.41 g of prey/crab/day or approximately 3% of their body weight is consumed monthly.

Similarity in feeding between sexes has previously been reported by Kun and Mikulich (1954), Kulichova (1955), and McLaughlin and Hebard (1961). Presumably the only instance when feeding differences between sexes would be apparent is if crabs were only sampled during the periods of male or female molting. These molting periods do not coincide as adults; males molt before females.

It is generally accepted that feeding takes place throughout the year, except during the molting-mating period when feeding ceases or is at a minimum (Feniuk, 1945; Kun and Mikulich, 1954; Kulichkova, 1955; and Cunningham, 1969). Kulichkova (1955) demonstrated that the duration of feeding before and after this period is short and does not extend beyond a few weeks. Only one period in the present study reflected a drastic reduction in feeding. King crabs that were examined in April in Kiliuda Bay were all newshell crabs that had recently undergone ecdysis. Feeding activity was minimal as only 16 out of 49 crabs contained food.

The analysis of the quantity of food consumed by king crabs at various sampling periods revealed that consumption in spring-summer months was significantly greater than fall-winter months (Table XLI). A complete seasonal account of king crab feeding activity does not exist. However, Takeuchi (1959) examined king crab feeding monthly from mid-May to mid-August and drew similar conclusions i.e., recently molted crabs in spring contain the largest quantity of food.

Differences in feeding between sampling areas (Table XLII) was due largely to crabs on the Kodiak Shelf containing more food than crabs from some nearshore locations. This was also evidenced when examing feeding differences by depth (Table XLIII). Crabs from the 126-150 m depth stratum contained significantly more food than crabs at the other stratum. King crabs taken from 126-150 m came from Stations 9, 10 and 12 on the Kodiak Shelf during June-July 1978. These three stations, located in the "Horse's Head", Sikalidak Trough and Kiliuda Trough, respectively, annually produce large commercially catches of king crabs (Powell *et al.*, 1974), and it is asummed that these areas have enchanced benthic productivity resulting from nutrient enriched water moving toward shore in these troughs (Hameedi, 1979).

The present study had similar conclusions concerning crab sizes and food groups as Kun and Mikulich (1954), Kulichkova (1955), Cunningham (1969), and Tarverdieva (1976) i.e., no significant differences were detected among size groups for any major food category. However, differences were evident in the overall quantity of food consumed by crabs of various sizes (Table XXXVIII). Test results imply that smaller crabs (<140 mm) feed more to capacity than larger crabs (>140 mm).

That crab classes 2 and 6 contained significantly more food than class 1, is presumably a reflection of the additional energy demand of class 2 and 6 crabs. These crabs are ones that recently molted and mated.

Since king crab stomach weight and volume (fullness) are well correlated, we used stomach weight in most statistical analyses. Stomach fullness is however a valid means of quantitatively assessing king crab food.

Most methods employed in obtaining an index of stomach fullness in decapod crustaceans are not comparable. Feniuk's (1945) method, also used by McLaughlin and Hebard (1961), was a cumulative ratio based on visual estimates of the cardiac, gastric mill, and pyloric regions of the stomach. Kun and Mikulich (1954), Kulichkova (1955), and Tarverdieva (1976), employing a method not fully comprehensible from the literature, also estimated stomach fullness by observation and fullness in parts per 10,000. Takeuchi (1959, 1967) derived a fullness index by using the ratio of crab body weight to food content weight. The Feeding Index of Fullness employed by Cunningham (1969) and the present study was derived from a ratio of observed volume to theoretical volume. Visual estimates of fullness are not determined by this method.

The only statistical analysis conducted on stomach fullness was by crab size groups. This analysis was presented as it showed more distinct size differences than did stomach weight.

When the percent of stomach fullness of all crabs from various size groups were compared, five different pairs of size groups were significantly different. All different pairs were small sizes versus large sizes (Table XXXIX). Furthermore, the test results show that crabs smaller than 140 mm were significantly fuller than crabs 140 mm or larger. Cunningham (1969) found that the smallest size group (98-120 mm) contained significantly more food than the three larger groups. Current observations also coincide with Logvinovich (1945), who found the ratio of food to body weight much higher in smaller king crabs.

The maximum stomach fullness of a single crab in the present study was 78%, while Cunningham (1979) reported a maximum stomach fullness of 86%.

The determination of king crab feeding intensity, as outlined in Objectives 5b and c, was precluded by food analyses utilizing stomach weight, volume, and fullness.

All previous studies dealing with food of king crabs conclude that at least one food group and/or species is dominant prey, and that prey composition is usually area specific. Differences in food groups and/or species between and within sampling areas were not statistically examined in the present study, however, some foods were obviously area specific. For example, barnacles which were taken mainly during spring-summer months only dominated king crab food in Anton Larsen and Kiliuda Bays. Similarly, fishes dominated the prey at only one area, Izhut Bay, in June and July. King crabs examined from the Kodiak Shelf in June-July 1978 came from nine widely separated stations. Although the foods from crabs examined at these stations were mainly pelecypods, distinct differences could be detected in the dominant prey items taken between stations. Clams were only important, in terms of total stomach weight, at Stations 7, 8, 9 and 10. Important prey at other stations were fishes at Stations 8, 10, 11, 12, 13 and 14; the pea crab, *Pinnixa occidentalis*, at Station 12; the brittle star, *Ophiura sarsi*, at Station 1 and the snow crab, *Chionoecetes bairdi* at Station 8.

Kun and Mikulich (1954) found wide food differences between king crabs from the Kurile Islands, Tartar Strait, and Okhotsk Sea. The sand dollar, *Echinarachnius parma*, dominated the prey weight of king crabs from the Kurile Islands. The sea urchin, *Strongylocentrotus* sp., dominated in the Gulf of Tartar, and the Greenland cockle, *Serripes groenlandicus*, dominated the prey in the southern Okhotsk Sea. Feder and Paul (in press) also found area food differences within Cook Inlet. Barnacles were the most frequently occurring prey in Kamishak Bay and a clam (*Spisula polynyma*) was most frequently taken in Kachemak Bay. The dominant prey of king crabs in a small region of the southeastern Bering Sea was echinoderms, specifically ophiuroids and echinoids (Cunningham, 1969), and yet echinoderms were the least important food group in the Kodiak region.

In addition to the regional food differences detected in the present study, the prey taken within any region was usually very diverse. Crabs collected *via* SCUBA within small sampling areas of Near Island Basin, McLinn Island, and Anton Larsen Bay contained 21 to 53 different prey taxa. Among the 98 different prey taxa taken by Kodiak Shelf king crabs, 73 taxa were identified from stomachs at a single station (Station 9), and 25 taxa were identified from a single crab (also at Station 9). The number of prey species was lowest in Izhut Bay crabs.

The chief prey items of king crabs in shallow Kodiak regions were soft-shelled clams and barnacles. Kulichkova (1955), who examined king crabs within a commercial king crab fishing region in the Okhotsk Sea, found that recently molted crabs mainly fed on the young of the clam *Tellina lutea*, while harshell crabs fed on the clam *Siliqua media*. He also noted that the chief food of recently molted king crabs taken from a depth of 16 m consisted of barnacles. He suggests that crabs need to replace the calcium carbonate lost during molting and that young clams and barnacles of shallow waters represent an abundant resource to fulfill this need. Feeding data in the present study indicate that barnacles, mainly *Balanus crenatus*, are prey throughout the year, but are an especially important component of the diet in the spring and summer months. The reproductive cycle of *B. crenatus* in Port Valdez, Alaska indicates major spawning occurs in the spring, although evidence exists suggesting successive spawning (e.g., June) after the major spawning effort (Feder *et al.*, 1979a). Crisp and Patell (1969) also reported that *B. crenatus* may produce several broods throughout the summer. Therefore, it is apparent that in the nearshore environment of Kodiak Island, where abundant food resources are necessary to replenish recently expended energy through molting and mating activities, barnacles in the advanced stages of reproduction (i.e., when gametogenic tissue is well-developed to just prior to naupliar release), as well as soft-shell clams, serve as excellent sources of food for king crabs.

Although barnacles are seldom prey for king crabs in the fall and winter months, Feder and Paul (in press) reported intensive feeding on barnacles, mainly *Balanus crenatus*, in November 1977 in lower Cook Inlet. Eighty-one percent of the crabs examined in Kamishak Bay had barnacles in their stomachs. The volcanic eruption of St. Augustine Island, lower Cook Inlet in February 1976 provided a new benthic substrate, pumice, suitable for barnacles settlement. Prior to the eruption, much of the surrounding area was composed of unconsolidated sediments unsuitable for barnacle settlement. Settlement was ultimately followed by the appearance of various species of crabs, and the subsequent predation by these crabs on the barnacles.

Molluscs dominate the food of king crabs in many northern waters. Feniuk (1945), Kulichkova (1955), and Takeuchi (1959, 1967) analyzed the feeding of king crabs in the Okhotsk Sea near the western shore of Kamchatka and found pelecypods and gastropods to dominate the diet. The works of McLaughlin and Hebard (1961), Cunningham (1969), Tarverdieva (1976) and Feder and Jewett (1980), in the southeastern Bering Sea, and Tarverdieva (1979) in the western Bering Sea also showed pelecypods and gastropods as important blue king crab food items. The most common molluscs fed upon by king crabs from most regions are protobranch clams, i.e., *Nuculana, Nucula* and *Yoldia*, snails of the family Trochidae. Other important clam prey are representatives of the family Tellinidae and Cardiidae.

Predation is the major method for king crab acquiring food, although there is evidence to show that king crabs are scavengers and that scavenging can be an important dietary stratagem. King crabs from many stations in Izhut Bay and the Kodiak continental shelf in June and July were dominated by fishes. During both sampling months in Izhut Bay, active feeding by large numbers of sooty shearwaters, black-legged kittiwakes and Steller sea lions was observed from the sampling vessel. The shearwaters and kittiwakes were feeding on the schooling fishes, capelin and Pacific sand lance (pers. comm. Gerald Sanger, USF&WS), and it is probable that the sea lions were also feeding on these fishes. Feniuk (1945) found fishes (2% frequency of occurrence) among stomach contents of king crabs off the west Kamchatka Shelf. Kukichkova (1955) reported that king crabs from the west coast of South Sakhalin contained herring at 10% of the total stomach fullness. He speculated that the fish were not alive when taken from the sea bed. Fishes were found in 13% of all Bering Sea king crabs examined by Cunningham (1969). In the cases where fishes are taken, it probably represents an important prey of opportunity. It is probable that schooling fishes that are heavily preyed upon near the surface are falling to the benthos after being injured or regurgitated by the predators. These fishes in turn are being taken in a scavenging manner by crabs. Live fishes, especially schooling fishes, are doubtfully taken by these relatively lethargic crabs.

The occurrence of plant material in the present study (33% frequency of occurrence) is the highest ever recorded. Among seven other studies in which king crabs have been reported to take plant material, the highest occurrence was 16.7% frequency of occurrence (Tarverdieva, 1976), although approximately 18% of the blue king crabs (*Paralithodes platypus*) examined by Tarverdieva (1979) contained this group. Most of the other plant occurrences were less than 10%. In some instances it is probable that algae is taken incidentally along with other prey. However, this group, which was frequently taken and represented 4.5% of the total wet weight in the present study, is presumably indicative of another opportunistic prey of the shallow waters around Kodiak Island.

Kun and Mikulich (1954) and Kulichkova (1955) reported that king crab food dominance is a reflection of the dominant benthic organisms. When the dominant species in pipe dredge material and king crab stomachs were compared from the Kodiak Shelf in June-July, it was determined that dominant crab prey species were similar to the dominant dredge species at only about one-half of the stations (see Tables XII and XXXII). Crabs from each station were collected along a 1.5-4.0 km transect (30 minute tow), whereas, pipe dredges were normally dragged across the sediment for not more than five minutes. Therefore, the fact that dominant species overlap (pipe dredge material and crab stomach contents) did not occur at more stations is presumably indicative of the patchy distribution of these benthic prey organisms at a station location. In order to better understand prey preferences *versus* prey availability, increased infaunal sampling is advised.

Few king crab predators have been identified in the Kodiak area. On one occasion Powell and Nickerson (1965) observed two horse crabs (*Erimacrus isenbeckii*) preying on juvenile king crabs when a pod disbanded after being disturbed by divers. The sculpin, *Hemilepidotus hemilepidotus*, is a known predator of post-larval king crabs 10 mm in length (Powell, pers. comm.). As many as five 2-year-old king crabs have also been found ingested by a single sculpin, and stomachs from 56 sculpins contained 110 crabs

(Powell, 1974). Pacific halibut (*Hippoglossus stenolepis*) are also known to prey on king crabs (Gray, 1964). Among the thousands of demersal fish stomachs examined from Gulf of Alaska and Bering Sea waters during the past five years king crabs were rarely found (Feder and Hoberg, 1980; Feder and Jewett, 1977, 1978, 1980; Feder *et al.*, 1979b; Jewett, 1978). It is assumed that the heaviest predation occurs during their planktonic stages. Sea otters have been observed to feed on mature king crabs in Prince William Sound (Jewett, pers. obser.). Exoskeleton of molted king crabs in the Kodiak region are consumed by the sea anemones, *Tealia crassicornis* (anonymous, 1976). King crabs are also the target of a major commercial fishery in the Kodiak Island region with (4.4×10^4) MT taken in the 1979 fishing season (G. Powell, pers. comm., 1980).

Chionoecetes spp. (Snow Crabs)

The feeding habits of *Chionoecetes* spp. have been examined by numerous investigators, and inferences from these studies suggest that food groups used by this genera are somewhat similar throughout its range. *Chionoecetes opilio elongatus* from Japanese waters fed primarily on brittle stars (*Ophiura* sp.), young *C. opilio elongatus*, and protobranch clams (*Portlandia* and *Nuculana*), in decreasing order of importance (Yasuda, 1967). *Chionoecetes opilio* from the Gulf of St. Lawrence fed mainly on clams (*Yoldia* spp.) and polychaetes (Powles, 1968). The deposit-feeding clam, *Nucula tenuis*, dominated the diet of *C. opilio* from Norton Sound and the Chukchi Sea (Feder and Jewett, 1978). Adult *Chionoecetes bairdi* and *C. opilio* from the southeastern Bering Sea fed mainly on polychaetes, and young crabs fed on crustaceans, polychaetes, and molluscs, in decreasing order of importance (Tarverdieva, 1976). Cunningham (1969) determined that molluscs (mainly pelecypods), crustaceans (mainly brachyuran crabs), and echinoderms (mainly ophiuroids) were the most important foods, in terms of dry weight, in 37 adult male *C. opilio* in the southeastern Bering Sea. Feder and Jewett (1980) also examined the food of *C. opilio* from the southeastern Bering Sea, and found the most frequently consumed foods to be polychaete worms and brittle stars (mainly *Ophiura* sp.).

Paul *et al.* (1979) examined stomachs of *C. bairdi* from lower Cook Inlet and found the main items to be clams (*Macoma* spp.), hermit crabs (*Pagurus* spp.), barnacles (*Balanus* spp.), and sediment, in decreasing order of importance. *Chionoecetes bairdi* in Port Valdez (Prince William Sound) contained polychaetes, clams, young *C. bairdi*, other crustaceans, and detrital material, in decreasing order of importance (Feder, unpub. data).

The few *Chionoecetes bairdi* that were previously examined from two bay of Kodiak Island mainly consumed polychaetes, clams (Nuculanidae), shrimps, crabs, plants, and sediment, in decreasing order of importance (Feder and Jewett, 1977).

Analysis of snow crabs in the present study > 40 mm revealed no significant difference in feeding between sexes, however, significant differences were apparent in the quantity of food consumed among feeding crabs from different sizes, classes, periods, areas, and depths.

Due to the lack of data on stomach flushing time among snow crabs, we can only assume that crabs > 40 mm empty their stomachs as often as king crab, i.e., an average of once daily. Therefore, by expanding the current consumption data of 0.81 g of food/crab/day, we calculate 24.3 g of food/crab/month or 8% of the body weight ($\bar{x}$ 300 g)/month.

Previous studies i.e., Feder and Jewett (1978) and Paul *et al.* (1979) also determined no difference in feeding between sexes of snow crabs.

Paul *et al.* examined the differences in the frequency of occurrence of prey in *Chionoecetes bairdi* of different size and determined that differences in prey were not apparent among different size crabs.

When only feeding snow crabs were examined by crab size groups in the present study, it was apparent that small crabs (40-99 mm) feed less to capacity than large crabs (100-179 mm) (Table LXVII). As previously mentioned, this is in contrast to that reported for king crabs where smaller crabs (80-139 mm) feed more to capacity than larger crabs (140-179 mm).

That newshell snow crabs consumed more food than oldshell is not surprising in view of the relatively lethargic nature of oldshell crabs. When oldshell crabs, especially those with attached epifauna, were brought to the surface they were much less lively than crabs with new exoskeletons. This seemly less energetic behavior presumably is a reflection of their activity in feeding. In extremely oldshell crabs the black microfungus *Phoma fimeti* encrusts the exoskeleton, including the eyes and mouth parts, thus hindering feeding (Van Hyning and Scarborough, 1973). Some classes of newshell king crab also consumed significantly more food than oldshell crab.

Snow crabs, like king crabs, migrate to shallow water to spawn in spring, however, the nearshore movement of snow crabs is not as closely aligned with the shallow subtidal region as king crabs. Inferences from the statistical test results show that snow crabs feed more to capacity during non-spawning periods i.e., winter months (November-February) (Table LXIX), while outside of the bays (Kodiak Shelf) (Table LXX), and in deep water (126-150 m) (Table LXXI). This, in part, is in contrast to king crabs where feeding to capacity apparently is greater during spring-summer months. The Kodiak Shelf areas and depth stratum 126-150 m was also most important for king crab food consumption.

The crustaceans which dominated the snow crab food biomass in the present study were mainly young snow crabs and pandalid shrimps. Unlike king crabs and Dungeness crabs, snow crabs have previously been described as cannibalistic (Yasuda, 1967; Powles, 1968; Feder and Jewett, 1977; and Paul *et al.*, 1979). Previous accounts of snow crabs consuming pandalid shrimps are limited (Yasuda, 1967; Paul *et al.*, 1979). Crangonid shrimps are also utilized by snow crabs (Feder and Jewett, 1977, 1978).

The importance of fishes as a prey for *Chionoecetes* in the present study appears to be greater than reported by other investigators (Yasuda, 1967; Powles, 1968; Feder and Jewett, 1977, 1978; Feder *et al.*, 1978). The previous highest percent frequency of occurrence value for fishes was 12% (Powles, 1968), although Yasuda (1967) listed the flatfish *Glyptocephalus stelleri* as "common" prey.

Bivalves, in particular protobranch species, are important snow crab prey in most areas where this crab genera occurs. In Alaskan waters many small, soft-shell species (*Nucula, Nuculana, Yoldia, Macoma* and *Axinopsida*) taken by snow crabs are also prey of king crabs, although king crabs also consume large, hard-shell bivalve species.

Sediment, a component in the stomach of many snow crabs in the present study, may represent a food resource of considerable importance, especially in young crabs (see Appendix B - Table II). Sediment frequently occurred among snow crab stomach contents examined by Feder and Jewett (1977, 1978), Feder *et al.* (1978), Tarverdieva (1976) and Paul *et al.* (1979). Sediment found in large crabs is presumably taken incidentally while taking target prey items. Yasuda (1967) found benthic diatoms to be abundant in *Chionoecetes opilio elongatus* in the Bering Sea, and postulated that diatoms and foraminiferans were taken indirectly with food and sediment. Moriarty (1977) reported on the occurrence of sediment in the food contents of five species of penaeid shrimps. The nutritional benefit of sediment intake to these shrimps appears to be derived from the film of organic carbon, inclusive of bacteria on sand grains. Snow crabs, especially young ones may be benefiting from sediment in the same manner as penaeid shrimps, in addition to utilizing the diatoms and foraminiferans within the sediment.

Sampling was conducted in order to compare the dominant potential prey items within an area with the dominant prey taken by snow crabs. The most numerous species within pipe dredge samples taken from the Kodiak Shelf in June-July 1978 and February 1979 were bivalves molluscs. Foremost among the bivalves was the tiny clam *Axinopsida serricata*. However, at stations where this clam was prevalent, it was seldom found within snow crabs (*Axinopsida* was frequently found in all snow crab sizes in Izhut and Kiliuda Bays). Other clams of less numerical importance than *Axinopsida*, i.e., *Nucula*, *Nuculana*, *Yoldia*, and *Macoma*, were also present in many pipe dredge stations and were consumed by snow crabs at respective stations (see Tables XII, LXI and LXIII). An important prey found within crabs from both June-July 1978 and February 1979 was juvenile snow crabs, and yet, this prey was not evident in any of the pipe dredge samples. Keep in mind that prey in snow crabs come from a much larger area (30 minutes of trawling) than the pipe dredge samples (5 minutes of dredging).

Difficulty in drawing conclusions as to whether snow crabs consume the dominant benthic forms also existed among the sediment sweeps and juvenile snow crab stomachs from Near Island Basin (see Table XIII and Appendix B - Table II). Dominant species within sweeps obtained in October 1979 were clams, specifically *Hiatella arctica* and *Clinocardium nuttallii*, snails (*Oenopota* sp. and *Lacuna variegata*) and gammarid amphipods. The most important prey within snow crabs from the same area were, in decreasing frequency of occurrence, *Lacuna*, *Axinopsida*, Amphipoda, and *Oenopota*. *Axinopsida* was not present in the October sweeps, which indicates a patchy distribution and that consumption must have occurred from an adjacent area.

These data indicate that snow crabs do not necessarily prey upon the dominant benthic species.

Snow crabs are one of the most commonly taken benthic prey in the Gulf of Alaska and the eastern Bering Sea. They are fed upon by at least seven species of biomass-dominating fishes (walleye pollock, Pacific cod, great sculpins, Irish lords, Pacific halibut, rex sole, rock sole, and flathead sole) and the king crab. Aside from being taken by these predators snow crabs are also cannibalistic. Consumption of pelagic stages of snow crabs is also expected to be high. This crab is also the target of a major commercial fishery in the Gulf of Alaska and the Bering Sea.

Pandalus borealis (Pink Shrimp)

Rice *et al.* (in press) who examined pandalid shrimps from Cook Inlet, Alaska observed 28 food categories in *Pandalus borealis*, with Crustacea, Polychaeta and diatoms the most common. *Pandalus hypsinotus* and *P. goniurus* mainly contained Crustacea, Polychaeta and Bivalvia. A high occurrence of sediment and unidentifiable organic matter was also observed for each species (approximately 60% dry weight sediment).

Data presented by Rice *et al.* (in press) and in the present study demonstrate that *Pandalus borealis* primarily feeds on the bottom and ingests a considerable amount of sediment. In contrast, Barr (1970) reported *P. borealis* in Kachemak Bay, Alaska feed in the water column on zooplankton. Another study in Kachemak Bay reported that the principal food of pandalid shrimps were detritus and diatoms (Crow, 1977).

The role of sediment among stomach contents of shrimps is unknown. It may be taken incidentally along with infaunal and small epifaunal prey or it may be directly taken where prey such as foraminiferans, diatoms and bacterial carbon associated with the sand grains are intentionally utilized.

Pycnopodia helianthoides (Sunflower Sea star)

The food of *Pycnopodia* collected in Prince William Sound was examined by Paul and Feder (1975) and Feder and Hoberg (1980). Most specimens examined by Paul and Feder (1975) came from the intertidal region although some subtidal specimens were taken. In general, intertidal *Pycnopodia* was feeding on a variety of food items, however, the most commonly encountered prey was the blue mussel *Mytilus edulis*. As many as 275 small *M. edulis* were found in a single stomach. Other important prey of intertidal specimens were the clams *Protothaca staminea*, *Saxidomus gigantea*, and unidentified small gastropods. Subtidal *Pycnopodia* prey was dominated by the protobranch clam *Nuculana fossa* and small gastropods. A second study on subtidal *Pycnopodia* in Prince William Sound revealed gastropods (i.e., *Mitrella gouldi*, *Solariella* spp. and *Nassarius mendicus*) and pelecypods (i.e., *Nuculana fossa* and *Psephidia lordi*) as dominant food items (Feder and Hoberg, 1980).

Subtidal specimens of *Pycnopodia* that were examined from the outer shelf of the northeastern Gulf of Alaska preyed almost entirely on gastropod molluscs and echinoderms. The echinoderms *Ctenodiscus crispatus* and *Ophiura sarsi* were the dominant organisms taken. Seventy-eight percent of the stations with *Pycnopodia* also contained *C. crispatus* and/or *O. sarsi*. Other foods of less importance, in order of diminishing frequency of occurrence, were the gastropods *Colus halli*, *Mitrella gouldi*, *Solariella obscura*, *Oenopota* sp. and *Natica clausa*, and the pelecypods *Serripes groenlandicus* and *Clinocardium ciliatum* (Jewett and Feder, 1976).

The food of subtidal *Pycnopodia* collected in Izhut Bay was similar to that found in most subtidal specimens from embayments i.e., small gastropods including *Oenopota* sp. and *Solariella* sp., and small clams including *Nuculana fossa*.

Mauzey *et al.* (1968) reported that *Pycnopodia* is capable of excavating for large clams. Large clams were seldom found among the stomach contents of *Pycnopodia* in Izhut Bay, although this sea star was observed, *via* SCUBA, within deep depressions in the sediment surface, presumably excavating for food.

One of the known predator and food competitors of *Pycnopodia* is the king crab. Many *Pycnopodia* observed by SCUBA were tightly squeezed into rock crevices when king crabs were in the vicinity. This behavior is assumed to be an avoidance response.

Gadus macrocephalus (Pacific Cod)

Data on stomach contents from some 4200 Pacific cod from the vicinity of Kodiak, Alaska have been presented (Jewett, 1978; Appendix C). Most of these fish were captured in crab pots; some 344 were taken in bottom trawls from the same area. Data were presented in percent frequency of occurrence and actual frequency of occurrence. Only summer sampling was conducted.

The most important food categories in both pot-caught and trawl-caught cod were fishes, crabs, shrimps and amphipods, in decreasing order of occurrence. The fish most frequently eaten was the walleye pollock *Theragra chalcogramma*, with Pacific sand lance *Ammodytes hexapterus*, and flatfishes (Pleuronectidae) also contributing frequently to the diet of cod. Juveniles of the snow crab *Chionoecetes bairdi* was the most frequently occurring food species, appearing in almost 40% of the stomachs examined.

Jewett (1978) also presents data which indicate little year-to-year variation in the summer diet of Pacific cod in the Kodiak area. He also suggests that food organisms shift in frequency with increased size in cod. Fish and cephalopod frequencies in the diet seemed to be directly related to size, while amphipod and polychaete frequencies were inversely related to size of predator.

Data from 29 Pacific cod from the southeastern Bering Sea, show pink shrimp as the most frequently consumed food item (Feder and Jewett, 1980). Walleye pollock, amphipods, and snow crabs were taken less frequently.

Miller *et al.* (1978) examined the stomach contents of Pacific cod from Port Townsend, Washington, and determined that crustaceans (mainly shrimp and mysids) were the main prey items. No significant difference in prey between sexes or fish sizes were observed.

Pacific cod examined from Kodiak Island (Ugak Bay) by Simenstad (1977) revealed that euphausiids were the most important prey, followed by fishes and shrimps. Another study of the food of Pacific cod of Kodiak showed pink shrimp as the major food of adult cod (Rogers *et al.*, 1979).

Food of Pacific cod examined in the present study was consistent with Pacific cod food found by all of the references mentioned above.

Myoxocephalus spp. and *Hemilepidotus jordani* (Sculpins)

Summer food of the sculpins *Myoxocephalus* spp. and *Hemilepidotus jordani*, near Kodiak Island were examined by Jewett and Powell (1979; Appendix D). Crabs were the dominant food of both genera. Major prey of *Myoxocephalus* spp. were the crabs *Chionoecetes bairdi* and *Hyas lyratus*, and fishes. Major prey comsumed by *H. jordani* were also *C. bairdi* and *H. lyratus*, in addition to another crab, *Oregonia gracilis*, and amphipods.

Shrimps, brachyuran crabs and fishes dominated the diet of *Myoxocephalus* spp. and *Hemilepidotus jordani* that were examined from the Kodiak region by Rogers *et al.* (1979).

Crabs, specifically *Chionoecetes bairdi*, were important in Izhut Bay *Myoxocephalus*, but not in those specimens examined from the Kodiak Shelf. Pink shrimp, *Pandalus borealis*, was an important prey for *Myoxocephalus* in both regions.

Crabs were important prey in *Hemilepidotus jordani* from the Kodiak Shelf.

Hippoglossoides elassodon (Flathead Sole)

Smith *et al.* (1978) examined 247 flathead sole in the Gulf of Alaska and 39 flathead sole from the Bering Sea. Euphausiids (probably all *Thysanoessa* spp.) and the brittle star, *Ophiura sarsi*, contributed most of the diet of the 139 feeding individuals from the Gulf of Alaska. The Bering Sea data suggest that the shrimp, *Pandalus borealis* is the most important spring prey, while mysids, amphipods, and *Ophiura sarsi* dominated summer feeding. Crangonid shrimps and juvenile pollock were the most important autumn prey in the Bering Sea.

Flathead sole from the Kodiak Island region that were examined by Rogers *et al.* (1979) preyed mainly on *Pandalus borealis*.

The dominant prey of flathead sole in the present study is consistent with flathead food as determined by Smith *et al.* (1978) and Rogers *et al.* (1979).

Lepidopsetta bilineata (Rock Sole)

Rock sole examined in the present study were feeding moderately. *Yoldia myalis* and polychaetes was the leading prey taken from the Kodiak Shelf. In general, food of rock sole from the Kodiak area is similar to that described by other authors.

Skalkin (1963) and Shubnikov and Lisovenko (1964) report that the Bering Sea diet consists chiefly of polychaetes followed by molluscs and crustaceans (mainly shrimp). Kravitz *et al.* (1976) found that rock sole in Oregon waters fed mainly on ophiuroids. Feeding is much reduced during the winter, and is most intense in June and July. Rogers *et al.* (1979) determined that polychaetes were the most important food in adult and juvenile rock sole from Kodiak although, clam siphons and gammarid amphipods were also important to juveniles.

Clam siphons were the main prey in rock sole caught by SCUBA in the shallow bays of Kodiak Island (Jewett, pers. obser.).

Of 166 Bering Sea rock sole examined by Smith *et al.* (1978), 80 were empty. Eleven families of polychaetes contributed most of the food consumed. Crustaceans, pelecypods, ophiuroids and fishes were also important.

Atheresthes stomias (Arrowtooth Flounder)

The few arrowtooth flounder examined in the present study were dominated by a fish diet.

Smith *et al.* (1978) examined arrowtooth flounder from the northeast Gulf of Alaska. Crustaceans were the most frequently occurring prey items consumed. Of this group, decapods were most often taken, with euphausiids the second most commonly consumed. Euphausiids were more important by number and volume. Shuntov (1965) reported that the walleye pollock was the principal food item of the arrowtooth flounder in the Bering Sea.

Fishes were the second most frequently occurring prey items. Members of the families Osmeridae, Gadidae, and Zoarcidae, in descending order of frequency of occurrence, were the most common.

Pleurogrammus monopterigius (Atka Mackerel)

Food of Atka mackerel from the coastal waters of north Kurile Island consisted mainly of planktonic crustaceans i.e. *Thysanoessa* spp. and *Calanus* spp. (Zolotov and Medveditsyna, 1978). Although Atka mackerel in the present study also contained euphausiids, the food was dominated by fishes. Another hexogrammid in Alaskan waters, *Ophiodon elongatus*, is also a voracious feeder of fishes such as herring and sand lance (Hart, 1973).

Anaplopoma fimbria (Sablefish)

The sablefish in the present study were full of sand lance. Shubnikov (1963) reported that food items of Bering Sea sablefish were also primarily fishes, including small gadids, flatfishes, gobies, capelin, and herring as well as benthic and nektonic invertebrates. Rogers *et al.* (1979) found that fish, mainly osmerids, accounted for 95% of the sablefish diet by weight.

Theragra chalcogramma (Walleye Pollock)

Pollock examined on the Kodiak Shelf by Jewett and Powell (unpub.) were mainly feeding on pink shrimp and euphausiids.

Rogers *et al.* (1979) determined that juvenile pollock from Kodiak Island waters fed mainly on chaetognaths, calanoid copepods, euphausiids and shrimp and adult fish fed most often on shrimp, euphausiids and fish (Ammodytidae).

Smith *et al.* (1978) examined pollock from the northeastern Gulf of Alaska and the southeastern Bering Sea. Gulf of Alaska fish (standard length $\bar{X} = 344 \pm 84$ mm) as well as Bering Sea fish (standard length $\bar{X} = 270 \pm 145$ mm) mainly contained euphausiids.

Young British Columbia pollock, from 4-22 mm standard length, fed on copepods and their eggs (Barraclough, 1967) while adults fed on shrimps, sand lance and herring (Hart, 1949). Armstrong and Winslow (1968) report Alaska pollock feeding on young pink, chum and coho salmon. Suyehiro (1942) reported small shrimps, benthic amphipods, euphausiids and copepods in the stomachs of pollock from the Aleutians. Andriyashev (1964) listed mysids and amphipods as the major foods of Bering Sea pollock with *Chionoecetes opilio* (snow crab) also present. He also reports that pollock from Peter the Great Bay and Sakhalin feed on surf smelt and capelin in the spring and shift to planktonic crustaceans in the summer. Nikolskii (1961) lists pollock food organisms from Asian waters as mysids, euphausiids, smelt and capelin.

Limanda aspera (Yellowfin Sole)

Yellowfin sole have previously been examined from the Kodiak vicinity by Simenstad (1977) and Rogers *et al.* (1979). Simenstad (1977) concluded that fishes (*Lycodes brevipes* and Osmeridae), polychaetes, and shrimps (*Crangon* spp. and Pandalidae) were the most important prey. Rogers *et al.* (1979) concluded that yellowfin sole ate a variety of foods but no organism dominated in both numbers and weight when all months were combined. Different foods, i.e. clam siphons and polychaetes did dominate at particular months.

The food of this species has also been examined in the Bering Sea (Kulichkova, 1955; Skalkin, 1963 and Andriyashev, 1964). Prey items identified in the present study were similar to of yellowfin sole examined by Skalkin (1963). Similar items were *Echiurus echiurus*, *Pandalus borealis*, and small clams, specifically *Yoldia*.

Apparently this species undergoes marked seasonal feeding intensity. The feeding intensity of Bering Sea yellowfin sole was highest in July and fell off during the fall as they began moving back to deeper water (Skalkin, 1963). Since 54% of the fish examined in the present study were empty in February, it is assumed that migration was in progress.

Isopsetta isolepis (Butter Sole)

The paucity of feeding data on butter sole in the present study and existing literature precludes interpretation of its food habits. Hart (1973) lists chaetopod marine worms, shrimps and sand dollars and young herring among butter sole stomach contents.

VIII. CONCLUSIONS

Forty-six permanent benthic stations were established in two bays — 29 stations in Izhut Bay and 17 stations in Kiliuda Bay. There is now a general, qualitative understanding, on a station basis for the months sampled, of the distribution and abundance of the major epifaunal invertebrates of the study area. The dominant invertebrate species had distinct biomass differences between the bays with snow crabs (*Chionoecetes bairdi*) and sunflower sea stars (*Pycnopodia helianthoides*) important in Izhut Bay and king crabs (*Paralithodes camtschatica*), snow crabs, and pink shrimps (*Pandalus borealis*) dominant in Kiliuda Bay.

The most important group, in terms of biomass, collected east of Afognak Island on the Kodiak shelf (March 1978) was the Echinodermata, specifically sea stars and sea urchins. King and snow crabs were the second-most important group from this area. Kodiak shelf sampling in June-July 1978 and February 1979 revealed king and snow crabs as the dominant species.

Stomachs of 809 king crabs collected in bays and on the shelf of Kodiak Island contained a wide variety of prey items. Food of king crabs from Izhut Bay was dominated by fishes, while crabs from Kiliuda Bay preyed primarily on molluscs, specifically clams. Food of king crabs from the Kodiak shelf consisted mainly of clams and cockles, although crustaceans and fishes were also important. King crabs taken inshore by SCUBA primarily contained acorn barnacles (*Balanus crenatus*) and clams. Barnacles were a major food resource for king crabs in Kiliuda Bay and inshore areas sampled by SCUBA in June and July.

Analysis of all king crabs revealed no significant difference in feeding between sexes, however, significant differences were apparent in the quantity of food consumed among feeding crabs from different sampling periods, depths, size groups, areas, and crab classes.

Paramount in this study of king crabs is the importance of the nearshore environment for molting, mating, and feeding activities.

A total of 1025 snow crabs (> 40 mm carapace width) and 475 ($\leq$ 40 mm) were examined for food contents. Important prey, in terms of biomass, in large crabs in Izhut Bay were fishes, shrimps, snow crabs, polychaetes, and miscellaneous clams. Important prey in large Kiliuda Bay snow crabs were pink shrimps, snow crabs, and miscellaneous clams. Sediment, miscellaneous clams, and polychaetes were most frequently found within small crabs in both Izhut and Kiliuda Bay. Snow crabs from the outer Kodiak shelf stations mainly contained miscellaneous crabs, clams, and shrimps.

Analysis of snow crabs > 40 mm revealed no significant difference in feeding between sexes, however, significant differences were apparent in the quantity of food consumed among feeding crabs from different periods, areas, depths, classes and size groups.

Frequently consumed prey among pink shrimps in Izhut and Kiliuda Bays were sediment, diatoms, crustaceans remains, and foraminiferans. Pink shrimps from the outer Kodiak shelf most frequently contained crustaceans, bivalves, foraminiferans, and fishes. Diatoms were nearly absent from pink shrimps from the outer shelf.

Molluscs dominated the diet of the sunflower sea star (*Pycnopodia helianthoides* from Izhut Bay. The snails *Oenopota* sp. and *Solariella* sp. were consistently taken as food. Feeding data on 11 species of primarily benthic-feeding fishes is also presented. Feeding data presented here, in conjunction with similar data from other Alaskan waters, now enhance our understanding of the trophic role of these organisms in their respective ecosystems. Comprehension of trophic interactions of benthic species is essential to comprehend the potential impact of oil on the crab-shrimp-dominated waters adjacent to Kodiak Island.

The importance of deposit-feeding clams in the diet of king and snow crabs in Kodiak waters has been demonstrated by preliminary feeding data collected there. It is suggested that an understanding of the relationship between oil, sediment, deposit-feeding clams, and crabs be developed in a further attempt to understand the possible impact of oil on the two commercially important species of crabs in the Kodiak area.

Initial assessment of data suggests that a few unique, abundant and/or large invertebrate species (king crabs, snow crabs, several species of clams) are characteristic of the bays investigated and that these species may represent organisms that could be useful for monitoring purposes.

IX. NEEDS FOR FURTHER STUDY

Although the trawling activities were satisfactory in a general way for qualitatively determining the distribution and abundance of epifauna, a substantial component of both bays — the infauna — was not sampled. Since epifaunal species represent important food items, it is essential that the use of grabs and/or dredges be accomplished at the bay stations in the near future.

The small try net made available on most cruises in the bays were inadequate for proper sampling of the epibenthos. It is possible that crabs, shrimps, and fishes were absent from the areas sampled; however, limited trawling with a 400-mesh Eastern otter trawl in stations adjacent to try net stations yielded significant catches of the above organisms. The try net was picking up small bottomfishes to satisfy objectives of ADF&G and FRI. However, based on the effectiveness of past trawl studies with the Eastern otter trawl, i.e. Ugak and Alitak, the try net did not properly satisfy our objectives requiring quantitative sampling of benthic invertebrates. It is highly recommended that an Eastern otter trawl as well as infaunal sampling devices, be used in the future if stations are to be used for monitoring activities.

An attempt should be made to quantify the carbon flow in the crab-shrimp dominated shelf adjacent to Kodiak. Serious consideration should ultimately be given to developing a predictive model embodying trophic interactions in Kodiak and adjacent waters.

In the spring of 1980, an attempt to document the nearshore migration of king crab *via* underwater photography will be made. Inherent in this documentation will be shots of feeding, molting, mating and other aggregative behavior of king crabs. An addendum to this Final Report will include the above observations.

X. REFERENCES

AEIDC. 1974. The western Gulf of Alaska - a summary of available knowledge, Arctic Envir. Information and Data Center, Univ. Alaska, Anchorage. 599 pp.

Alaska Department of Fish and Game (ADF&G). 1976. A Fish and Wildlife Resource Inventory of the Cook Inlet - Kodiak Areas. Under contract to Alaska Coastal Management Program, Division of Policy Development and Planning, Anchorage. 2 Vols., Vol. 2 - Fisheries. 434 pp.

Andriyashev, A. P. 1964. Fishes of the northern seas of the USSR. Transl. Isr. Prog. Sci. Transl. 617 pp.

Anonymous, 1976. An ocean biodegrader. *Sea Frontiers* 22(1):32-34.

Arctic Environmental Information and Data Center. 1975. Kadyak - a background for living. Univ. Alaska, AEIDC Publ. No. B-75, Sea Grant Publ. No. 75-9. 326 pp.

Armstrong, R. H. and P. C. Winslow. 1968. An incidence of walleye pollock feeding on salmon young. *Trans. Amer. Fish. Soc.* 97:202-203.

Baker, J. M. (ed). 1976. *Marine Ecology and Oil Pollution.* John Wiley and Sons, New York, N.Y. and Toronto, Ont. 566 pp.

Barr, L. 1970. Alaska's fishery resources - the shrimps. U.S. Fish. Wildl. Serv. Fish. Leafl. 631 pp.

Barraclough, W. E. 1967. Data record. Number, size and food of larval and juvenile fish caught with a tow boat surface trawl in the Strait of Georgia, April 25-29, 1966. Fish. Res. Bd. Can. MS Rep. Ser. 922:54.

Boesch, D. F., C. H. Hershner and J. H. Milgram. 1974. *Oil Spills and the Marine Environment.* Ballinger Publishing Co., Cambridge, Mass. 114 pp.

Bright, D. B. 1967. life histories of the king crab, *Paralithodes camtschatica*, and the "Tanner" crab, *Chionoecetes bairdi*, in Cook Inlet, Alaska, Univ. Southern California, Ph.D. thesis. 265 pp.

Bright, D. B., F. E. Durham, and J. W. Knudsen. MS, 1960. King crab investigations of Cook Inlet, Alaska. Department of Biology, Allan Hancock Foundation, Univ. Southern California at Los Angeles. 180 pp.

Chebanov, S. M. 1965. Some data on the biology of the Kamchatka king crab, *Paralithodes camtschatica* (Tilesius) in Bristol Bay. Tr. VNIRO 58:91-94.

Crisp, D. J. and B. Patell. 1969. Environmental control of the breeding of three boreo-arctic cirripedes. *Mar. Biol.* 2:283-295.

Crow, J. H. 1977. Food habits of shrimp in Kachemak Bay, Alaska. *In* L. L. Trasky, L. B. Flagg and D. C. Burbank (eds.), *Environmental Studies in Kachemak Bay and Lower Cook Inlet*. Alaska Dept. Fish & Game. 27 pp.

Cunningham, D. T. 1969. A study of the food and feeding relationships of the Alaskan king crab *Paralithodes camtschatica*. Master thesis, San Diego State College. 78 pp.

Donaldson, W. 1977. Kodiak Alaska Tanner Crab (*Chionoecetes bairdi*) Research. Comm. Fish. Res. and Devel. Act. Proj. No. 5-35-R. Rept. Per. 7/1/73-6/30/76. 140 pp.

Dunn, O. J. 1964. Multiple comparisons using rank sums. *Technometrics* 6(3):241-252.

Feder, H. M. 1978. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of the Kodiak Shelf, Cook Inlet and NEGOA. Renewal proposal FY '79 to NOAA, OCSEAP. 68 pp.

Feder, H. M. and M. K. Hoberg. 1980. The distribution, abundance, biomass and diversity of the epifauna of three bays (Port Etches, Zaikof Bay and Rocky Bay) in Prince William Sound, with notes on feeding biology. Final Rept. to NOAA, R.U. #5. 86 pp.

Feder, H. M. and S. C. Jewett. 1977. The distribution, abundance, and diversity of the epifaunal benthic organisms in two bays (Alitak and Ugak) of Kodiak Island, Alaska. Final Rept. to NOAA, R.U. #P29, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 79 pp.

Feder, H. M. and S. C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, the southeastern Chukchi Sea, and Kotzebue Sound. Inst. Mar. Sci. Rept. R78-1, Univ. Alaska, Fairbanks. 124 pp.

Feder, H. M. and S. C. Jewett. 1980. Survey of the epifaunal invertebrates of the southeastern Bering Sea with notes on the feeding biology of selected species. Inst. Mar. Sci. Rept. R78-5, Univ. Alaska, Fairbanks. pp.

Feder, H. M. and G. E. Matheke, in press. The distribution, abundance community structure and trophic relationships of the benthic infauna of the northeastern Gulf of Alaska. Inst. Mar. Sci. Rept. R78-8, Univ. Alaska, Fairbanks.

Feder, H. M. and G. Mueller. 1975. Environmental Assessment of the Northeast Gulf of Alaska: Benthic Biology. First year Final Rept. to NOAA. 200 pp.

Feder, H. M. and A. J. Paul. In press. Food of the king crab, *Paralithodes camtschatica* and the dungeness crab, *Cancer magister*, in Cook Inlet, Alaska. Proc. Nat'l Shellfish. Assoc.

Feder, H. M., S. C. Jewett, M. Hoberg, A. J. Paul, J. McDonald, G. Matheke, and J. Rose. 1978. Distribution, abundance, community structure, and trophic relationships of the nearshore benthos of the Kodiak Shelf, Cook Inlet, northeast Gulf of Alaska and the Bering Sea. Annual Rept. to NOAA, OCSEAP, R.U. #281/5/303. 315 pp.

Feder, H. M., G. E. Keiser and G. J. Mueller. 1979a. A study of the intertidal region of Port Valdez, Prince William Sound, Alaska. Inst. Mar. Sci. Rept. R79-2, Chapters 8-10, Univ. Alaska, Fairbanks. 222 pp.

Feder, H. M., A. J. Paul, M. Hoberg, S. C. Jewett, K. McCumby, J. McDonald, R. Rice, P. Shoemaker. 1979b. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of Cook Inlet and NEGOA. Annual Rept. to NOAA, R.U. #5. 77 pp.

Feniuk, V. F. 1945. Analiz soderzhimogo zheludkov Kamchatskogo kraba (Analysis of stomach contents of king crab) [in English, Japanese, and Russian]. Izvestiia Tikhookeanskii nauchno-issledovatel skii Institut Rybnogo Khoziaistava i Okeanografii, Vladivostok. Izv. TINRO [J. Pac. Sci. Inst. Fish. Oceanogr., Vladivostok] 19:71-78.

Gray, G. W., Jr. 1964. Halibut preying on large Crustacea. *Copeia* 3:590.

Gray, G. W. and G. C. Powell. 1966. Sex ratios and distribution of spawning king crabs in Alitak Bay, Kodiak Island, Alaska (Decapoda Anomura, Lithodidae). *Crustaceana* 10(3):303-309.

Hart, J. L. 1949. Food of fish of the cod family. Fish. Res. Can. Pac. Prog. Rept. 79:35-36.

Hart, J. L. 1973. Pacific fishes of Canada. *Fish. Res. Bd. Canada Bull.* 180. 740 pp.

Hameedi, M. J. 1979. Kodiak marine environment and planned petroleum development, Chapter 8. 73 pp. *In* Kodiak Interim Synthesis Report, 1980 (Draft).

Ishii, Sugai and Abe. 1929. Fundamental research report of the king crab fishing in the sea near Sakhalin. Rept. of the Sakhalin Fish. Exp. Sta. 6:107.

Ivanov, B. G. 1969. The biology and distribution of the northern shrimp, *Pandalus borealis* Kr., in the Bering Sea and the Gulf of Alaska. FAO Fish. Rept. 57(3):800-810.

Jewett, S. C. 1978. Summer food of the Pacific cod, *Gadus macrocephalus*, near Kodiak Island, Alaska. *Fish. Bull.* 76(3):700-706.

Jewett, S. C. and H. M. Feder. 1976. Distribution and abundance of some epibenthic invertebrates of the northeast Gulf of Alaska, with notes on the feeding biology of selected species. Inst. Mar. Sci. Rept. R76-8, Univ. Alaska, Fairbanks. 61 pp.

Jewett, S. C. and G. C. Powell. 1979. Summer food of the sculpins, *Myoxocephalus* spp. and *Hemilepidotus jordani*, near Kodiak Island, Alaska. Mar. Sci. Comm., Inst. Mar. Sci., Univ. Alaska, Fairbanks 5(4&5):315-331.

Kajita, Y. 1925. The investigation report of the king crab. Rept. of the Hokkaido Fisheries Exp. Station. pp. 12-13.

Kajita, Y. and T. Nakazawa. 1932. The investigation of the king crab. The Investigation Report of Fisheries 27. 163 pp.

Karinen, J. F. and S. D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting tanner crabs, *Chionoecetes bairdi*. *Mar. Fish. Rev.* 36(7):31-37.

Kawasaki, M. 1955. Research on king crab in the southeastern part of the Bering Sea in 1954 (in Japanese). Jap. Fish. Agency Res. Div. Rept. 75 pp.

Kingsbury, A. P. and K. E. James. 1971. Abundance and composition of king crabs in the Alitak and Kaguyak Bay areas during April and June, 1970. Alaska Dept. Fish Game Inf. Leafl. No. 152. 42 pp.

Kingsbury, A. P., N. P. Johnson, and R. J. Kaiser. 1974. King crab study. Comm. Fish. Res. and Devel. Act. Proj. No. 5-22-R. Completion Rept. for period 7/1/69-6/30/72. 93 pp.

Kravitz, M. J., W. G. Pearcy and M. P. Guin. 1976. Food of five species of co-occurring flatfishes on Oregon's continental shelf. *Fish. Bull.* 74(4):984-990.

Kulichkova. V. A. 1955. Pitanie Kamchatskogo kraba v vesenne-letnii period u Beregov Kamchatki i Sakhalina (Feeding of Kamchatka crabs during the spring-summer period on the shores of Kamchatka and Saghalin) [in Russian and English]. Izv. TINRO [J. Pac. Sci. Inst. Fish. Oceanogr., Vladivostok] 43:21-42.

Kun, M. S., and L. V. Mikulich. 1954. Sostav pishchi dalnevostochnykh promy slovikh krabov v letnii period (Diet composition of Far Eastern crabs of commercial quality during the summer) [in Russian, Japanese, and English]. Izv. TINRO [J. Pac. Sci. Inst. Fish. Oceanogr., Vladivostok] 41:319-332.

Lewis, J. R. 1970. Problems and approaches to base-line studies in coastal communities. FAO Tech. Conf. on Mar. Pollution and its Effect on Living Resources and Fishing. FIR:MP 70/E-22. 7 pp.

Logvinovich, D. N. 1945. Aquaria observations on the feeding of king crabs. *J. Pac. Sci. Inst. Fish. Oceanogr.*, Vladivostok 19:1-79.

McDonald, K. B. and K. K. Petersen. 1976. Kodiak Island: physical environment, biota, and potential problems related to oil exploration. A scientific report based primarily on OCSEAP-sponsored research. Science Applications, Inc., Boulder, Colorado. 146 pp.

McLaughlin, P. A. and J. F. Hebard. 1961. Stomach contents of the Bering Sea king crab. *Intl. North Pac. Fish. Comm. Bull.* 5:5-8.

McMullen, J. C. 1967. King crab *Paralithodes camtschatica* (Tilesius) offshore breeding study on Marmot Flats, Kodiak Island, Spring of 1967. ADF&G Informational Leaflet No. 112. 12 pp.

Malins, D. C., (ed.). 1977. *Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms.* Biological effects. Academic Press, Inc., New York, N.Y., Vol. 2. 512 pp.

Marukawa, H. 1933. Biological and fishery research on Japanese king crab, *Paralithodes camtschatica* (Tilesius) [in English and Japanese]. *J. Imp. Fish. Exp. Sta.*, Tokyo 4(37):152 pp.

Mauzey, K. P., C. Birkeland and P. K. Dayton. 1968. Feeding behavior of asteroids and escape responses of their prey in the Puget Sound region. *Ecol.* 49(4):603-619.

Mecklenburg, T. A., S. D. Rice, and J. F. Karinen. 1976. Effects of Cook Inlet crude oil water soluble fractions on survival and molting of king crab (*Paralithodes camtschatica*) and coonstripe shrimp (*Pandalus hypsinotus*) larvae. Proceeding of the 27th Alaska Science Conference. Abstracts Vol. 1. 183 pp.

Miller, B. S., W. A. Karp and G. E. Walters. 1978. Pacific cod (*Gadus macrocephalus*) studies in Port Townsend Bay, Washington. Final Rept. to U.S. Navy - Rept. No. FRI-UW-7821. 69 pp.

Moriarty, D. J. W. 1977. Quantification of carbon, nitrogen and bacterial biomass in the food of some penaieid prawns. *Aust. J. Mar. Freshwater Res.* 28:113-118.

Nakazawa, T. 1912. Research on king crab produced in Hokkaido (in Japanese). *J. Zool.* 24(249):1-13.

Nelson-Smith, A. 1973. *Oil Pollution and Marine Ecology.* Paul Elek (Scientific Books) Ltd., London. 260 pp.

Nikolskii, G. V. 1961. Special Ichthyology. Israel Program for Sci. Transl.

Olson, T. A. and F. J. Burgess (eds.). 1967. *Pollution and Marine Ecology.* Interscience, New York. 364 pp.

Paul, A. J. and H. M. Feder. 1975. The food of the sea star *Pycnopodia helianthoides* (Brandt) in Prince William Sound, Alaska. *Ophelia* 14:15-22.

Paul, A. J., H. M. Feder and S. C. Jewett. 1979. Food of the snow crab, *Chionoecetes bairdi* Rathbun, 1974, from Cook Inlet, Alaska (Decapoda, Majidae). *Crustaceana*, Suppl. 5:62-68.

Pearson, T. H. 1971. The benthic ecology of Loch Linnhe and Loch Eil, a sea loch system on the west coast of Scotland. III. The effect on the benthic fauna of the introduction of pulp mill effluent. *J. Exp. Mar. Biol. Ecol.* 6:211-233.

Pearson, T. H. 1972. The effect of industrial effluent from pulp and paper mills on the marine benthic environment. *Proc. Roy. Soc. Lond. B.* 130:469-485.

Pearson, T. H. 1975. The benthic ecology of Loch Linnhe and Loch Eil, a sea loch system on the west coast of Scotland. IV. Changes in the benthic fauna attributable to organic enrichment. *J. Exp. Mar. Biol. Ecol.* 20:1-41.

Powell, G. C. 1964. Fishing mortality and movements of adult male king crabs, *Paralithodes camtschatica* (Tilesius), released seaward from Kodiak Island, Alaska. Trans. Am. Fish. Soc., 93(3):295-300.

Powell, G. C. 1974. Gregarious king crabs. *Sea Frontiers* 20(4):206-211.

Powell, G. G., R. Kaiser, and R. Peterson. 1974. King crab study, comp. rep. for period 1/1/72-6/30/73. Proj. No. 5-30-R, Comm. Fish. Res. and Devel. Act. 70 pp.

Powell G. C. and R. B. Nickerson. 1965. Aggregations among juvenile king crabs (*Paralithodes camtschatica*, Tilesius) Kodiak, Alaska. *Animal Behaviour* 13(2-3):374-380.

Powles, H. 1968. Distribution and biology of the spider crab *Chionoecetes opilio* in the Magdalen Shallows, Gulf of St. Lawrence. Fish. Res. Bd. Can. Mar. Rept. Ser. No. 997. 106 pp.

Rhoads, D. C. 1974. Organism-sediment relations on the muddy sea floor. *Oceanogr. Mar. Biol. Ann. Rev.* 12:263-300.

Rice, R. L., K. I. McCumby and H. M. Feder. In press. Food of *Pandalus borealis, Pandalus hypsinotus*, and *Pandalus goniurus* (Pandalidae, Decapoda) from Lower Cook Inlet, Alaska. Proc. Nat'l. Shellfish Assoc.

Rogers, D. E., D. J. Rabin, B. J. Rogers, K. Garrison and M. Wangerin. 1979. Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island - including ichthyoplankton, meroplankton (shellfish), zooplankton, and fish. Annual Rept. to NOAA, R.U. #553. 123 pp.

Ronholt, L. L., H. H. Shippen and E. S. Brown. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass, 1948-76: A historical review. NOAA/OCSEAP R.U. #174, Final Rept., 2:1-955.

Rosenberg, D. H. 1972. A review of the oceanography and renewable resources of the northern Gulf of Alaska. Inst. Mar. Sci. Rept. R72-23, Univ. Alaska, Fairbanks. Sea Grant Rept. 73-3. 690 pp.

Rosenberg, R. 1973. Succession in benthic macrofauna in a Swedish fjord subsequent to the closure of a sulphite pulp mill. *Oikos* 24:244-258.

Rumyantsev, L. E. 1945. [the migration of crab along the southern part of the west coast of Kamchatka.] Izvestiia Tikhookeanskogo N.-I. Instituta Rybnogo Khoziaistva I Okeanografii, 19:55-70.

Shubnikov, D. A. 1963. Data on the biology of sablefish of the Bering Sea. (Transl. from Russian by Isr. Prog. Sci. Transl. Jerusalem, as Soviet Fish. Inv. Northeast Pacific, Part I p. 287-296, Avail from Nat'l. Tech. Inf. Serv., Springfield, Va. as TT67-51203.)

Shubnikov, D. A. and L. A. Lisovenko. 1964. Data on the biology of rock sole of the southeastern Bering Sea. *In: Sov. Fish. Inv. N. Pac. Pt. II*: 220-226. Isr. Prog. Sci. Transl. TT67-51204.

Shuntov, V. P. 1965. Distribution of the Greenland halibut and arrowtooth halibuts in the North Pacific. (Transl. from Russian by Isr. Prog. Sci. Transl., Jerusalem, as Soviet Fish. Invest. Northeast Pacific, Part IV, p. 220-226. Avail. from Nat'l. Tech. Inf. Serv., Springfield, Va. as TT67-51206.)

Simenstad, C. A. 1977. ADF&G-OCS fish food habits analysis. Final Rept. to Alaska Dept. Fish and Game. 27 pp.

Skalkin, V. A. 1963. Diet of flatfishes in the southeastern Bering Sea. *In: Sov. Fish. Invest. N. Pac. Pt. I*: 235-250. Isr. Prog. Sci. Transl. TT67-51203. 333 pp.

Smith, J. E. (ed.). 1968. *'Torrey Canyon' Pollution and Marine Life*. Cambridge Univ. Press, Cambridge. 196 pp.

Smith, R., A. Paulson, J. and J. Rose. 1978. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. Ann. Rept. to NOAA R.U. #284, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 70 pp.

Straughan, D. 1971. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Allan Hancock Foundation, Univ. Southern California, Los Angeles. 425 pp.

Suyehiro, Y. 1942. A study on the digestive system and feeding habits of fish. *Jap. J. Zool.* 10:1-303.

Takeuchi, I. 1959. Food of king crab (*Paralithodes camtschatica*) off the west coast of Kamchatka in 1958. *Bull. Hokkaido Reg. Fish. Res. Lab.* 20:67-75. (Transl. from Jap.-Fish. Res. Bd. Can. Transl. Ser. No. 1193.)

Takeuchi, I. 1967. Food of king crab, *Paralithodes camtschatica*, off the west coast of the Kamtchatka peninsula, 1958-1964. *Bull. Jap. Sea Reg. Fish. Res. Lab.* 33:32-44. (Transl. from Jap.-Fish. Res. Bd. Can. Transl. Ser. No. 1194.).

Tarverdieva, M.I. 1976. Feeding of the Kamchatka king crab, *Paralithodes camtschatica* and tanner crabs, *Chionoecetes bairdi* and *Chionoecetes opilio* in the southeastern part of the Bering Sea. *Sov. J. Mar. Biol.* 2(1):34-39.

Tarverdieva, M. I. 1979. Feeding habits of deep blue crab, *Paralithodes platypus*, in the Bering Sea. *Sov. J. Mar. Biol.* 5(1):39-42.

Van Huning, J. M. and A. M. Scarborough. 1973. Identification of fungal encrustation of the shell of the snow crab (*Chionoecetes bairdi*). *J. Fish. Res. Bd. Can.* 30(11):1738-1739.

Vinogradov, L. G. 1945. Godichnyi tsikl zhizni i migratsii kraba v serernoi chasti zapadnokam-chatskogo shelfa (The annual life cycles and migrations of crabs in the northern part of the west Kamchatka shelf) [in Russian and Japanese]. Izv. TINRO [J. Pac. Sci. Inst. Fish. Oceanogr., Vladivostok] 19:3-54.

Wallace, M. M., C. J. Pertuit and A. H. Huatum. 1949. Contributions to the biology of the king crab, *Paralithodes camtschatica* (Tilesius). U.S. Fish Wildl. Serv., Fish. Leafl. 340:1-49.

Watson, 1969. Biological investigations on the spider crab, *Chionoecetes opilio*. Proc. meeting on Atlantic crab fishery development. Can. Fish. Rept. 13:24-27.

Yasuda, T. 1967. Feeding habits of the zawaigani, *Chionoecetes opilio elongatus*, in Wakasa Bay. I. Specific composition of the stomach contents. *Bull. Jap. Soc. Sci. Fish.* 33(4):315-319 (Fish. Res. Bd. Can. Transl. Ser. No. 1111).

Zar, J. H. 1974. *Biostatistical Analysis*. Prentice-Hall, Inc. 620 pp.

Zenkevitch, L. A. 1963. *Biology of the Seas of the USSR*. George Allen and Unwin., Ltd., London. 955 pp.

Zolotov, O. G. and A. V. Medveditsyna. 1978. Feeding habits of the one-finned greenling in coastal waters of the north Kurile Islands. *Sov. J. Mar. Biol.* 4(4):790-792.

XI. APPENDICES

Appendix A - Benthic Trawl and SCUBA Stations Occupied in the Kodiak Region, 1978-79

APPENDIX A

BENTHIC TRAWL AND SCUBA STATIONS OCCUPIED IN THE KODIAK REGION, 1978-79

Izhut Bay

Station Name	Latitude	Longitude	Depth, m
2[1]	58°08.2'	152°09.5'	66- 80
3[2]	58°08.5'	152°10.3'	82-102
4[2]	58°09.1'	152°10.5'	62- 69
5[1]	58°09.1'	152°09.3'	38
6[2]	58°09.1'	152°11.5'	89
7[2]	58°08.7'	152°12.8'	179-201
8[2]	58°09.3'	152°12.7'	101-201
9[2]	58°09.7'	152°13.2'	164-189
501[1]	58°15.9'	152°14.6'	23- 24
502[1]	58°15.8'	152°14.6'	16- 17
526[1]	58°12.6'	152°12.8'	42- 93
527[1]	58°12.6'	152°12.9'	18- 97
551[1]	58°11.0'	152°12.5'	20- 44
552[1]	58°11.1'	152°12.3'	14- 27
553[1]	58°11.1'	152°12.1'	9- 37
554[1]	58°11.7'	152°21.1'	20- 42
555[1]	58°09.4'	152°18.5'	9- 16
557[1]	58°10.7'	152°18.5'	22- 97
576[1]	58°09.3'	152°07.4'	16- 50
577[1]	58°09.0'	152°07.9'	33- 45
580[1]	58°08.9'	152°09.6'	20- 56
582[1]	58°08.5'	152°10.2'	30- 71
583[1]	58°09.4'	152°17.5'	15- 27
584[1]	58°09.0'	152°12.0'	182
585[1]	58°08.0'	152°08.0'	55- 64
676[1]	58°08.3'	152°10.0'	41
677[1]	58°08.7'	152°10.0'	36
678[1]	58°08.8'	152°11.3'	55
679[1]	58°09.5'	152°13.5'	80

Kiliuda Bay

Station Name	Latitude	Longitude	Depth, m
1[2]	57°16.5'	152°53.1'	69- 73
2[2]	57°16.2'	152°54.7'	79- 91
3[2]	57°16.5'	152°53.5'	73- 82
4[2]	57°17.4'	152°58.2'	55- 73
5[2]	57°18.0'	152°57.6'	73- 90
6[2]	57°18.8'	152°57.7'	84- 91
7[1]	57°16.6'	152°54.0'	75- 88
501[1]	57°20.6'	152°09.5'	33- 40
576[1]	57°19.9'	152°55.0'	25- 60
577[1]	57°20.4'	152°53.3'	14- 27
578[1]	57°20.4'	152°53.8'	18- 27
579[1]	57°17.5'	152°51.0'	15- 27
580[1]	57°17.5'	152°51.8'	22- 27
SHR[1]	57°18.5'	153°04.0'	91-100
676[1]	57°18.0'	152°57.3'	84
677[1]	57°18.3'	152°58.5'	66
678[1]	57°17.2'	152°58.3'	49

SCUBA Stations

Station Name	Latitude	Longitude	Depth, m
Near Is. Basin[1]	57°47.0'	152°03.0'	5- 11
McLinn Is.[1]	57°46.2'	152°27.0'	9- 15
Anton Larsen Bay #1[1]	57°52.0'	152°37.4'	5
Anton Larsen Bay #2[1]	57°52.5'	152°39.0'	6- 9

APPENDIX A
CONTINUED

Kodiak Shelf - March 1978

Station Name	Start		Finish		Depth, m
1	57°58.6'	151°40.8'	57°57.3'	151°42.4'	104-115
2[3]	57°57.8'	151°41.1'	57°56.6'	151°42.7'	99-112
4	58°13.0'	151°11.4'	58°11.2'	151°09.6'	161-166
6	58°10.9'	151°07.9'	58°09.5'	151°05.9'	144-159
7	58°12.0'	151°10.3'	58°10.8'	151°08.5'	157-166
8[3]	58°13.6'	151°13.8'	58°12.2'	151°11.8'	150-165
10[3]	57°57.9'	151°41.2'	57°56.0'	151°41.3	84-101
12	58°00.0'	150°06.2'	57°58.1'	150°04.8'	245-251
14	57°56.8'	150°05.9'	57°55.3'	150°04.4'	237-241
15	57°57.5'	150°02.6'	57°56.4'	150°01.5'	243-252
17	57°57.7'	150°07.8'	57°56.1'	150°08.4'	221-229
18	57°51.3'	150°10.2'	57°49.7'	150°09.9'	192-201
20[3]	57°50.8'	150°08.2'	57°48.9'	150°08.6'	188-199
22	57°50.7'	150°07.7'	57°49.6'	150°08.7'	283-287
24	58°05.1'	150°06.9'	58°03.6'	150°07.5'	309-322
26[4]	58°04.1'	150°07.0'	58°02.9'	150°08.6'	276-320

Kodiak Shelf - June-July 1978 and February 1979

Station Name	Start		Finish		Depth, m
1[5]	58°12.4'	151°05.9'	58°17.6'	150°57.5'	67- 73
2[5]	56°54.4'	154°47.5'	56°54.4'	154°47.0'	55- 53
3[6]	57°48.7'	150°40.9'	57°47.7'	150°42.0'	91- 93
4[6]	57°29.1'	151°30.6'	57°29.0'	151°33.5'	123-159
5[6]	56°42.7'	153°10.8'	56°44.4'	153°10.7'	157
6[5]	56°40.9'	153°41.2'	56°40.4'	153°38.0'	101-139
7[6]	56°46.9'	154°18.5'	56°48.4'	154°20.7'	53- 58
8[6]	56°51.9'	154°27.5'	56°50.7'	154°25.4'	73
9[6]	56°42.5'	153°41.7'	56°43.4'	153°44.9'	139-141
10[6]	57°02.1'	153°25.7'	57°00.9'	153°27.7'	126
11[6]	57°12.8'	152°59.0'	57°13.4'	152°56.5'	117
12[6]	57°13.5'	152°48.0'	57°12.0'	152°47.4'	130-139
13[5]	58°09.1'	152°13.5'	58°07.7'	152°12.0'	172-174
14[6]	58°04.9'	152°16.8'	58°05.5'	152°15.7	175-177

APPENDIX A
CONTINUED

Kodiak Shelf - June-1978 and February 1979

Station Name	Start		Finish		Depth, m
22[5]	57°28.2'	152°06.2'	57°27.4'	152°06.6'	49- 46
23[7]	57°22.2'	152°25.5'	57°20.5'	152°25.4'	56
44[6]	57°18.9'	151°19.1'	57°17.2'	151°17.2'	150
S 2[7]	57°56.9'	151°18.8'	57°58.1'	151°18.8'	69- 71
S 3[7]	58°02.5'	151°49.1'	58°03.4'	151°46.6'	163-166
S 5[7]	57°56.5'	152°00.9'	57°57.1'	151°58.2'	196-199

---

[1] Mid-point coordinate

[2] Start coordinate

[3] Only trophic data collected

[4] Invertebrate data and trophic data collected

[5] Occupied only in June-July 1978

[6] Occupied in June-July 1978 and February 1979

[7] Occupied only in February 1979

Appendix B - Table I - Intestine Contents of King Crabs from the Kodiak Island Region, 1978

APPENDIX B - TABLE I

INTESTINE CONTENTS OF KING CRABS (*PARALITHODES CAMTSCHATICA*) FROM THE KODIAK ISLAND REGION, 1978

(N) = Number of Intestines

	Percent Frequency of Occurrence Based on	
Intestine Contents	Total Intestines	Intestines with Food
Izhut Bay - 7-22 June 1978	N = 9	N = 8
Unidentified material (7)	77.8	87.5
Pisces (5)	55.6	62.5
Sediment (3)	33.3	37.5
Pelecypoda (1)	11.1	12.5
Clinocardium ciliatum (1)	11.1	12.5
Clinocardium sp. (1)	11.1	12.5
Natantia (1)	11.1	12.5
Echinodermata (1)	11.1	12.5
Plant (1)	11.1	12.5
Golden fiber (1)	11.1	12.5
Empty (1)	11.1	-
Izhut Bay - 9-12 July 1978	N = 18	N = 13
Mud (8)	44.4	61.5
Pisces (6)	33.3	46.2
Pelecypoda (5)	27.8	38.5
Empty (5)	27.8	-
Nuculana fossa (4)	22.2	30.8
Polychaeta (3)	16.7	23.1
Gastropoda (2)	11.1	15.4
Crustacea (2)	11.1	15.4
Hydrozoa (1)	5.6	7.7
Axinopsida serricata (1)	5.6	7.7
Clinocardium ciliatum (1)	5.6	7.7
Clinocardium sp. (1)	5.6	7.7
Macoma sp. (1)	5.6	7.7
Plant (1)	5.6	7.7
Golden fiber (1)	5.6	7.7
Kiliuda Bay - 10-22 April 1978	N = 49	N = 17
Empty (23)	65.3	-
Polychaeta (5)	10.2	29.4
Nuculana fossa (5)	10.2	29.4
Decopoda (5)	10.2	29.4
Nucula tenuis (3)	6.1	17.6
Unidentified animal remains (3)	6.1	17.6
Pelecypoda (2)	4.1	11.8
Ophiuroidea (2)	4.1	11.8

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Hydrozoa (1)	2.0	5.9
Foraminifera (1)	2.0	5.9
Macoma sp. (1)	2.0	5.9
Clinocardium nuttallii (1)	2.0	5.9
Serripes groenlandicus (1)	2.0	5.9
Gastropoda (1)	2.0	5.9
Trochidae (1)	2.0	5.9
Polinices sp. (1)	2.0	5.9
Balanus sp. (1)	2.0	5.9
Natantia (1)	2.0	5.9
Sediment (1)	2.0	5.9
Kiliuda Bay - 7-22 June 1978	N = 50	N = 48
Nuculana fossa (29)	58.0	60.4
Decapoda (26)	52.0	54.2
Balanus sp. (22)	44.0	45.8
Pelecypoda (20)	40.0	41.7
Polychaeta (19)	38.0	39.6
Macoma sp. (16)	32.0	33.3
Axinopsida serricata (13)	26.0	27.1
Foraminifera (10)	20.0	20.8
Nucula tenuis (10)	20.0	20.8
Clinocardium ciliatum (10)	20.0	20.8
Gastropoda (10)	20.0	20.8
Unidentified animal remains (10)	20.0	20.8
Turridae (7)	14.0	14.6
Plant (6)	12.0	12.5
Clinocardium sp. (4)	8.0	8.3
Trochidae (4)	8.0	8.3
Ophiuroidea (4)	8.0	8.3
Golden fiber (4)	8.0	8.3
Modiolus modiolus (3)	6.0	6.3
Balanus crenatus (3)	6.0	6.3
Paguridae (3)	6.0	6.3
Crabs (3)	6.0	6.3
Hydrozoa (2)	4.0	4.2
Peisidice aspera (2)	4.0	4.2
Pectinariidae (2)	4.0	4.2
Limpet (2)	4.0	4.2
Unidentified material (2)	4.0	4.2
Sediment (2)	4.0	4.2

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Empty (2)	4.0	-
Idanthyrsus armatus (1)	2.0	2.1
Cistenides sp. (1)	2.0	2.1
Serripes groenlandicus (1)	2.0	2.1
Spisula polynyma (1)	2.0	2.1
Pandora sp. (1)	2.0	2.1
Hiatella arctica (1)	2.0	2.1
Puncturella sp. (1)	2.0	2.1
Natica clausa (1)	2.0	2.1
Ectoprocta (1)	2.0	2.1
Chionoecetes bairdi (1)	2.0	2.1
Pisces (1)	2.0	2.1
Byssal thread (1)	2.0	2.1
Kiliuda Bay - 9-21 July 1978	N = 71	N = 69
Nuculana fossa (47)	66.2	68.1
Nucula tenuis (30)	42.3	43.5
Clinocardium ciliatum (27)	38.0	39.1
Axinopsida serricata (26)	36.6	37.6
Macoma sp. (25)	35.2	36.2
Balanus sp. (20)	28.2	29.0
Gastropoda (16)	22.5	23.2
Decapoda (15)	21.1	21.7
Chionoecetes bairdi (15)	21.1	21.7
Balanus crenatus (12)	16.9	17.4
Pectinariidae (8)	11.3	11.6
Clinocardium sp. (8)	11.3	11.6
Foraminifera (7)	9.9	10.1
Polychaeta (7)	9.9	10.1
Serripes groenlandicus (6)	8.5	8.7
Pectinidae (6)	8.5	8.7
Idanthyrsus armatus (5)	7.0	7.2
Hiatella arctica (5)	7.0	7.2
Trichtropis cancellata (5)	7.0	7.2
Turridae (4)	5.6	5.7
Unidentified animal remains (4)	5.6	5.7
Flabelligeridae (3)	4.2	4.3
Pelecypoda (3)	4.2	4.3
Pandora sp. (3)	4.2	4.3
Ophiuroidea (3)	4.2	4.3

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Owenia fusiformis (2)	2.8	2.9
Stylarioides sp. (2)	2.8	2.9
Spiochaetopterus costarum (2)	2.8	2.9
Yoldia sp. (2)	2.8	2.9
Mya sp. (2)	2.8	2.9
Naticidae (2)	2.8	2.9
Natica clausa (2)	2.8	2.9
Oenopota sp. (2)	2.8	2.9
Collisella sp. (2)	2.8	2.9
Strongylocentrotus droebachiensis (2)	2.8	2.9
Pisces (2)	2.8	2.9
Plant (2)	2.8	2.9
Sediment (2)	2.8	2.9
Empty (2)	2.8	-
Hydrozoa (1)	1.4	1.4
Crucigera sp. (1)	1.4	1.4
Veneridae (1)	1.4	1.4
Saxidomus gigantea (1)	1.4	1.4
Clinocardium nuttallii (1)	1.4	1.4
Modiolus modiolus (1)	1.4	1.4
Trochidae (1)	1.4	1.4
Cylichna alba (1)	1.4	1.4
Buccinum sp. (1)	1.4	1.4
Turbonilla sp. (1)	1.4	1.4
Balanus rostratus (1)	1.4	1.4
Natantia (1)	1.4	1.4
Paguridae (1)	1.4	1.4
Oregonia gracilis (1)	1.4	1.4
Ophiura sarsi (1)	1.4	1.4
Echinarachnius parma (1)	1.4	1.4
Echiurus echiurus (1)	1.4	1.4
Kiliuda Bay - 8-13 August 1978	N = 44	N = 40
Macoma sp. (18)	40.9	45.0
Axinopsida serricata (14)	31.8	35.0
Nucula tenuis (12)	27.3	30.0
Nuculana fossa (12)	27.3	30.0
Sediment (10)	22.7	25.0
Gastropoda (8)	18.2	20.0
Animal material (8)	18.2	20.0
Polychaeta (7)	15.9	17.5

BEST DOCUMENT AVAILABLE

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Clinocardium ciliatum (6)	13.6	15.0
Yoldia sp. (5)	11.3	12.5
Foraminifera (4)	9.1	10.0
Balanus sp. (4)	9.1	10.0
Golden fiber (4)	9.1	10.0
Empty (4)	6.8	-
Pelecypoda (3)	6.8	7.5
Natantia (3)	6.8	7.5
Pectinariidae (2)	4.5	5.0
Paguridae (2)	4.5	5.0
Chionoecetes bairdi (2)	4.5	5.0
Plant (2)	4.5	5.0
Hydrozoa (1)	2.3	2.5
Nereis sp. (1)	2.3	2.5
Spiochaetopterus costarum (1)	2.3	2.5
Spionidae (1)	2.3	2.5
Myriochele heeri (1)	2.3	2.5
Spisula polynyma (1)	2.3	2.5
Cylichnidae (1)	2.3	2.5
Cumacea (1)	2.3	2.5
Crustacea (1)	2.3	2.5
Ophiura sarsi (1)	2.3	2.5
Strongylocentrotus droebachiensis (1)	2.3	2.5
Echinarachnius parma (1)	2.3	2.5
Pisces (1)	2.3	2.5
Zostera sp. (1)	2.3	2.5
Kiliuda Bay - 4-17 November 1978	N = 55	N = 49
Unidentified animal material (38)	69.1	77.6
Sediment (29)	52.7	59.2
Macoma sp. (23)	41.8	46.9
Axinopsida serricata (20)	36.4	40.8
Pollutant (14)	25.5	28.6
Empty (14)	25.5	-
Chionoecetes bairdi (12)	21.8	24.5
Foraminifera (11)	20.0	22.4
Gastropoda (8)	14.5	16.3
Nucula tenuis (6)	10.9	12.2
Nuculana fossa (4)	7.3	8.2
Pisces (4)	7.3	8.2
Decapoda (3)	5.5	6.1
Plant (2)	3.6	4.1
Polychaeta (2)	3.6	4.1

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on	
	Total Intestines	Intestines with Food
Yoldia sp. (2)	3.6	4.1
Turbonilla sp. (1)	1.8	2.0
Sabellidae (1)	1.8	2.0
Spiochaetopterus sp. (1)	1.8	2.0
Polynoidae (1)	1.8	2.0
Serripes groenlandicus (1)	1.8	2.0
Lyonsia bracteata (1)	1.8	2.0
Trochidae (1)	1.8	2.0
Balanus rostratus (1)	1.8	2.0
Shrimp (1)	1.8	2.0
Pandalus sp. (1)	1.8	2.0
Paguridae (1)	1.8	2.0
Echiuridae (1)	1.8	2.0
Kodiak Shelf - 19 June - 9 July 1978	N = 196	N = 184
Unidentified animal remains (127)	64.8	69.0
Nucula tenuis (117)	59.7	63.6
Nuculana fossa (110)	56.1	59.8
Sediment (104)	53.1	56.5
Axinopsida serricata (98)	50.0	53.3
Blue thread (63)	32.1	34.2
Foraminifera (50)	25.5	27.2
Gastropoda (47)	24.0	25.5
Clinocardium ciliatum (45)	23.0	24.5
Pandora grandis (43)	21.9	23.4
Chionoecetes bairdi (43)	21.9	23.4
Decapoda (42)	21.4	22.8
Pisces (40)	20.4	21.7
Polychaeta (27)	13.8	14.7
Echiuridae (26)	13.3	14.1
Ophiuridae (26)	13.3	14.1
Cucumaria sp. (26)	13.3	14.1
Cardiomya sp. (24)	12.2	13.0
Macoma sp. (23)	11.7	12.5
Pelecypoda (23)	11.7	12.5
Plant (21)	10.7	11.4
Cylichna alba (21)	10.7	11.4
Pinnixa occidentalis (21)	10.7	11.4
Serripes groenlandicus (18)	9.2	9.8
Natantia (18)	9.2	9.8
Golden fiber (18)	9.2	9.8
Diamphiodia craterodmeta (16)	8.2	8.7

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on	
	Total Intestines	Intestines with Food
Pandalidae (15)	7.7	8.2
Red thread (13)	6.6	7.1
Dentalium sp. (12)	6.1	6.5
Amphipoda (12)	6.1	6.5
Empty (12)	6.1	-
Cistenides sp. (10)	5.1	5.4
Amphiuridae (10)	5.1	5.4
Lyonsia bracteata (8)	4.0	4.3
Yoldia sp. (7)	3.6	3.8
Ophiura sarsi (7)	3.6	3.8
Myriochele heeri (6)	3.1	3.3
Turbonilla sp. (6)	3.1	3.3
Clinocardium nuttallii (5)	2.6	2.7
Owenia fusiformis (4)	2.0	2.2
Turridae (4)	2.0	2.2
Naticidae (4)	2.0	2.2
Crustacea (4)	2.0	2.2
Echinoidea (4)	2.0	2.2
Echinodermata (4)	2.0	2.2
Pecten sp. (3)	1.5	1.6
Clinocardium sp. (3)	1.5	1.6
Paguridae (3)	1.5	1.6
Hydrozoa (2)	1.0	1.1
Retusa sp. (2)	1.0	1.1
Spisula polynyma (2)	1.0	1.1
Lepidepecreum comatum (2)	1.0	1.1
Balanus sp. (2)	1.0	1.1
Pugettia gracilis (2)	1.0	1.1
Bryozoa (2)	1.0	1.1
Strongylocentrotus sp. (2)	1.0	1.1
Feather (2)	1.0	1.1
Nematoda (1)	0.5	0.5
Pectinariidae (1)	0.5	0.5
Onuphidae (1)	0.5	0.5
Cyclocardia sp. (1)	0.5	0.5
Psephidia lordi (1)	0.5	0.5
Cerithiopsis sp. (1)	0.5	0.5
Alvinia sp. (1)	0.5	0.5
Polinices sp. (1)	0.5	0.5
Bankia setacea (1)	0.5	0.5
Diastylis paraspinulosa (1)	0.5	0.5
Green thread (1)	0.5	0.5

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on	
	Total Intestines	Intestines with Food
Kodiak Shelf - 14-24 February 1979	N = 22	N = 14
Unidentified animal material (14)	63.6	100.0
Empty (8)	36.4	-
Sediment (8)	36.4	57.1
Nuculana spp. (6)	27.3	42.9
Blue thread (4)	18.2	28.6
Macoma sp. (3)	13.6	21.4
Pisces (3)	13.6	21.4
Yoldia sp. (2)	9.1	14.3
Paguridae (2)	9.1	14.3
Ophiuroidea (2)	9.1	14.3
Polychaeta (1)	4.5	7.1
Alcyondium sp. (1)	4.5	7.1
Nucula tenuis (1)	4.5	7.1
Psephidia lordi (1)	4.5	7.1
Spisula polynyma (1)	4.5	7.1
Pelecypoda (1)	4.5	7.1
Polinices sp. (1)	4.5	7.1
Shrimp (1)	4.5	7.1
Chionoecetes bairdi (1)	4.5	7.1
Red thread (1)	4.5	7.1
Near Island Basin - 17 May 1978 (SCUBA)	N = 35	N = 35
Plant (22)	62.9	62.9
Pelecypoda (20)	57.1	57.1
Foraminifera (12)	34.3	34.3
Unidentified animal remains (12)	34.3	34.3
Hydrozoa (11)	31.3	31.3
Owenia fusiformis (11)	31.3	31.3
Pectinariidae (10)	28.6	28.6
Strongylocentrotus sp. (10)	28.6	28.6
Macoma sp. (9)	25.7	25.7
Golden fiber (9)	25.7	25.7
Sand (9)	25.7	25.7
Polychaeta (8)	22.9	22.9
Gastropoda (8)	22.9	22.9
Balanus sp. (7)	20.0	20.0
Trochidae (7)	20.0	20.0
Protothaca staminea (6)	17.1	17.1
Hiatella arctica (5)	14.3	14.3
Saxidomus gigantea (3)	8.6	8.6
Crabs (3)	8.6	8.6
Echinodermata (3)	8.6	8.6

APPENDIX B - TABLE I

CONTINUED

	Percent Frequency of Occurrence Based on	
Intestine Contents	Total Intestines	Intestines with Food
Crucigera zygophora (2)	5.7	5.7
Amphipoda (2)	5.7	5.7
Decapoda (2)	5.7	5.7
Ophiuroidea (2)	5.7	5.7
Byssal thread (2)	5.7	5.7
Sabellariidae (1)	2.9	2.9
Eteone sp. (1)	2.9	2.9
Serpulidae (1)	2.9	2.9
Polyplacophora (1)	2.9	2.9
Yoldia sp. (1)	2.9	2.9
Clinocardium sp. (1)	2.9	2.9
Serripes groenlandicus (1)	2.9	2.9
Lyonsia bracteata (1)	2.9	2.9
Pectinidae (1)	2.9	2.9
Cyclostremella concordia (1)	2.9	2.9
Polinices sp. (1)	2.9	2.9
Fusitriton oregonensis (1)	2.9	2.9
Limpet (1)	2.9	2.9
Echinoidea (1)	2.9	2.9
Diamphiodia craterodmeta (1)	2.9	2.9
Asteroidea (1)	2.9	2.9
Fabriciinae (1)	2.9	2.9
Pisces (1)	2.9	2.9
Egg (1)	2.9	2.9
Unidentified material (1)	2.9	2.9
Near Island Basin - 15 June 1978 (SCUBA)	N = 32	N = 31
Sand (25)	78.1	80.6
Pelecypoda (21)	65.6	67.7
Plant (21)	65.6	67.7
Balanus sp. (20)	62.5	64.5
Hydrozoa (19)	59.4	61.3
Golden fiber (16)	50.0	51.6
Protothaca staminea (13)	40.6	41.9
Unidentified animal remains (13)	40.6	41.9
Pectinariidae (12)	37.5	38.7
Crabs (12)	37.5	37.5
Strongylocentrotus sp. (10)	31.3	32.3
Owenia fusiformis (8)	25.0	25.8
Macoma sp. (6)	18.8	19.4
Mya sp. (6)	18.8	19.4
Amphipoda (5)	15.6	16.1

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on	
	Total Intestines	Intestines with Food
Clinocardium sp. (4)	12.5	12.9
Gastropoda (4)	12.5	12.9
Pisces (3)	9.4	9.7
Foraminifera (2)	6.3	6.5
Polychaeta (2)	6.3	6.5
Saxidomus gigantea (2)	6.3	6.5
Axinopsida serricata (2)	6.3	6.5
Balanus crenatus (2)	6.3	6.5
Unidentified material (2)	6.3	6.5
Myriochele heeri (1)	3.1	3.2
Hiatella arctica (1)	3.1	3.2
Polinices sp. (1)	3.1	3.2
Mopalia sp. (1)	3.1	3.2
Balanus hesperius (1)	3.1	3.2
Echiurus sp. (1)	3.1	3.2
Ophiuroidea (1)	3.1	3.2
Byssal thread (1)	3.1	3.2
Empty (1)	3.1	-
Near Island Basin - 11 May 1979 (SCUBA)	N = 21	N = 21
Unidentified animal material (21)	100.0	100.0
Sediment (18)	85.7	85.7
Plant (16)	76.2	76.2
Balanus crenatus (14)	66.7	66.7
Foraminifera (12)	57.1	57.1
Pectinariidae (12)	57.1	57.1
Macoma sp. (12)	57.1	57.1
Protothaca staminea (11)	52.4	52.4
Owenia fusiformis (9)	42.9	42.9
Hiatella arctica (9)	42.9	42.9
Strongylocentrotus droebachiensis (9)	42.9	42.9
Pelecypoda (8)	38.1	38.1
Thread (7)	33.3	33.3
Clinocardium sp. (4)	19.0	19.0
Alvinia sp. (3)	14.3	14.3
Amphipoda (3)	14.3	14.3
Gastropoda (2)	9.5	9.5
Crustacea (2)	9.5	9.5
Mya sp. (1)	4.8	4.8
Glycymeris subobsoleta (1)	4.8	4.8
Axinopsida serricata (1)	4.8	4.8
Shrimp (1)	4.8	4.8
Chionoecetes bairdi (1)	4.8	4.8
Asteroidea (1)	4.8	4.8

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
McLinn Island - 19 May 1978 (SCUBA)	N = 49	N = 49
Plant (30)	61.2	61.2
Pectinariidae (29)	59.2	59.2
Pelecypoda (29)	59.2	59.2
Strongylocentrotus sp. (28)	57.1	57.1
Foraminifera (23)	46.9	46.9
Golden fiber (21)	42.9	42.9
Macoma sp. (19)	38.8	38.8
Balanus sp. (16)	32.7	32.7
Tichotropis cancellata (15)	30.6	30.6
Hiatella arctica (14)	28.6	28.6
Trochidae (13)	26.5	26.5
Protothaca staminea (12)	24.5	24.5
Crabs (10)	20.4	20.4
Ophiuroidea (10)	20.4	20.4
Sand (10)	20.4	20.4
Gastropoda (9)	18.4	18.4
Hydrozoa (8)	16.3	16.3
Amphipoda (8)	16.3	16.3
Polychaeta (6)	12.2	12.2
Unidentified animal remains (6)	12.2	12.2
Owenia sp. (5)	10.2	10.2
Decapoda (5)	10.2	10.2
Tonicella lineata (3)	6.1	6.1
Mya sp. (3)	6.1	6.1
Echinodermata (3)	6.1	6.1
Bryozoa (2)	4.1	4.1
Crustacea (2)	4.1	4.1
Pisces (2)	4.1	4.1
Charcoal ? (2)	4.1	4.1
Unidentified material (2)	4.1	4.1
Serpulidae (1)	2.0	2.0
Dexiospira sp. (1)	2.0	2.0
Mitrella gouldi (1)	2.0	2.0
Axinopsida serricata (1)	2.0	2.0
Clinocardium ciliatum (1)	2.0	2.0
Spisula polynyma (1)	2.0	2.0
Modiolus sp. (1)	2.0	2.0
Crepidula sp. (1)	2.0	2.0
Fusitriton oregonensis (1)	2.0	2.0
Homalopoma sp. (1)	2.0	2.0
Polyplacophora (1)	2.0	2.0

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on	
	Total Intestines	Intestines with Food
Collisella sp. (1)	2.0	2.0
Mopalia sp. (1)	2.0	2.0
Crangonidae (1)	2.0	2.0
Ostracoda (1)	2.0	2.0
Atylus sp. (1)	2.0	2.0
Echinoidea (1)	2.0	2.0
Wood (1)	2.0	2.0
Feather (1)	2.0	2.0
Byssal thread (1)	2.0	2.0
McLinn Island - 9 May 1979 (SCUBA)	N = 16	N = 11
Unidentified animal material (11)	68.8	100.0
Sediment (10)	62.5	90.9
Amphiuridae (7)	43.8	63.6
Foraminifera (6)	37.5	54.5
Chionoecetes bairdi (6)	37.5	54.5
Pelecypoda (5)	31.3	45.5
Empty (5)	31.3	45.5
Pisces (4)	25.0	36.4
Plant (3)	18.8	36.4
Polychaeta (3)	18.8	36.4
Macoma (3)	18.8	36.4
Balanus crentatus (3)	18.8	36.4
Decapoda (3)	18.8	36.4
Blue thread (3)	18.8	36.4
Hydrozoa (2)	12.5	18.2
Gastropoda (2)	12.5	18.2
Thread (2)	12.5	18.2
Pectinariidae (1)	6.3	9.1
Alvinia sp. (1)	6.3	9.1
Solariella sp. (1)	6.3	9.1
Mitrella gouldi (1)	6.3	9.1
Balanus sp. (1)	6.3	9.1
Pagurus sp. (1)	6.3	9.1
Crustacea (1)	6.3	9.1
Echiuridae (1)	6.3	9.1
Unidentified material (1)	6.3	9.1
Golden fiber (1)	6.3	9.1
Plastic (1)	6.3	9.1

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Anton Larsen Bay #1 - 16 June 1978 (SCUBA)	N = 31	N = 27
Plant (18)	58.1	66.7
Pelecypoda (15)	48.4	55.6
Sand (15)	48.4	55.6
Balanus sp. (11)	35.5	40.7
Hydrozoa (9)	29.0	33.3
Owenia fusiformis (8)	25.8	29.6
Pectinariidae (8)	25.8	29.6
Protothaca staminea (7)	22.6	25.9
Golden fiber (7)	22.6	25.9
Macoma sp. (6)	19.4	22.2
Balanus crenatus (6)	19.4	22.2
Unidentified animal remains (5)	16.1	18.5
Gastropoda (4)	12.9	14.8
Polinices sp. (4)	12.9	14.8
Unidentified material (4)	12.9	14.8
Empty (4)	12.9	-
Polychaeta (3)	9.7	11.1
Mytilus edulis (3)	9.7	11.1
Crabs (3)	9.7	11.1
Trochidae (2)	6.5	7.4
Littorina sitkana (2)	6.5	7.4
Decapoda (2)	6.5	7.4
Wood (2)	6.5	7.4
Foraminifera (1)	3.2	3.7
Lumbrineris sp. (1)	3.2	3.7
Tellinidae (1)	3.2	3.7
Clinocardium sp. (1)	3.2	3.7
Axinopsida serricata (1)	3.2	3.7
Alvinia compacta (1)	3.2	3.7
Limpet (1)	3.2	3.7
Balanus hesperius (1)	3.2	3.7
Balanus glandula (1)	3.2	3.7
Amphipoda (1)	3.2	3.7
Anton Larsen Bay #2 - 16 June 1978 (SCUBA)	N = 21	N = 19
Plant (14)	66.7	73.7
Hydrozoa (11)	52.4	57.9
Balanus crenatus (11)	52.4	57.9
Hiatella arctica (5)	23.8	26.3
Balanus sp. (5)	23.8	26.3
Pectinariidae (4)	19.0	21.1
Macoma sp. (4)	19.0	21.1

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Gastropoda (4)	19.0	21.1
Pelecypoda (3)	14.3	15.8
Mytilus edulis (3)	14.3	15.8
Protothaca staminea (3)	14.3	15.8
Crabs (3)	14.3	15.8
Strongylocentrotus sp. (2)	9.5	10.5
Unidentified animal material (2)	9.5	10.5
Sand (2)	9.5	10.5
Empty (2)	9.5	-
Foraminifera (1)	4.8	5.3
Polychaeta (1)	4.8	5.3
Nuculana fossa (1)	4.8	5.3
Axinopsida serricata (1)	4.8	5.3
Nucula tenuis (1)	4.8	5.3
Veneridae (1)	4.8	5.3
Alvinia compacta (1)	4.8	5.3
Trochidae (1)	4.8	5.3
Paguridae (1)	4.8	5.3
Echiurus sp. (1)	4.8	5.3
Asteroidea (1)	4.8	5.3
Wood (1)	4.8	5.3
Unidentified remains (1)	4.8	5.3
Anton Larsen Bay #2 - 8 May 1979 (SCUBA)	N = 17	N = 17
Unidentified animal material (16)	94.1	94.1
Plant (15)	88.2	88.2
Alvinia sp. (10)	58.8	58.8
Balanus crenatus (10)	58.8	58.8
Hiatella arctica (9)	52.9	52.9
Pectinariidae (8)	47.1	47.1
Gastropoda (8)	47.1	47.1
Plastic (8)	47.1	47.1
Macoma sp. (6)	35.3	35.3
Clinocardium sp. (6)	35.3	35.3
Foraminifera (5)	29.4	29.4
Mya sp. (5)	29.4	29.4
Pelecypoda (5)	29.4	29.4
Strongylocentrotus droebachiensis (5)	29.4	29.4
Chionoecetes bairdi (4)	23.5	23.5
Sediment (4)	23.5	23.5
Barleeia sp. (3)	17.6	17.6
Mytilus edulis (3)	17.6	17.6
Protothaca staminea (3)	17.6	17.6

APPENDIX B - TABLE I

CONTINUED

Intestine Contents	Percent Frequency of Occurrence Based on Total Intestines	Intestines with Food
Crustacea (3)	17.6	17.6
Oenopota sp. (2)	11.8	11.8
Clinocardium ciliatum (2)	11.8	11.8
Glycymeris subobsoleta (2)	11.8	11.8
Margarites costalis (2)	11.8	11.8
Balanus sp. (2)	11.8	11.8
Amphipoda (2)	11.8	11.8
Polychaeta (1)	5.9	5.9
Axinopsida serricata (1)	5.9	5.9
Nuculana sp. (1)	5.9	5.9
Pandora sp. (1)	5.9	5.9
Littoria sp. (1)	5.9	5.9
Margarites sp. (1)	5.9	5.9
Turbonilla sp. (1)	5.9	5.9
Gammaridae (1)	5.9	5.9
Echiuridae (1)	5.9	5.9
Asteroidea (1)	5.9	5.9
Thread (1)	5.9	5.9

Appendix B - Table II - Stomach Contents of Snow Crab < 40 mm Carapace Width from the Kodiak Island Region, 1978-79

APPENDIX B - TABLE II

STOMACH CONTENTS OF SNOW CRAB (*CHIONOECETES BAIRDI*) ≤40 mm CARAPACE WIDTH FROM THE KODIAK ISLAND REGION, 1978-79

(N) = Number of Stomachs with a Particular Prey Item

	Percent Frequency of Occurrence Based on	
Stomach Contents	Total Stomachs	Stomachs with food
Izhut Bay - 11-14 April 1978	N = 13	N = 13
Polychaeta (7)	53.8	53.8
Crustacea (5)	38.5	38.5
Gastropoda (4)	30.8	30.8
Pelecypoda (3)	23.1	23.1
Foraminifera (2)	15.4	15.4
Sediment (2)	15.4	15.4
Plant (1)	7.7	7.7
Trochidae (1)	7.7	7.7
Decapoda (1)	7.7	7.7
Echinodermata (1)	7.7	7.7
Unidentified material (1)	7.7	7.7
Izhut Bay - 11-14 May 1978	N = 72	N = 65
Sediment (32)	44.4	49.2
Polychaeta (26)	36.1	40.0
Unidentified animal material (25)	34.7	38.5
Decapoda (24)	33.3	36.9
Golden fiber (22)	30.6	33.8
Nucula tenuis (19)	26.4	29.2
Pelecypoda (18)	25.0	27.7
Axinopsida serricata (17)	23.6	26.2
Echinodermata (13)	18.1	20.0
Pisces (8)	11.1	12.3
Foraminifera (7)	9.7	10.8
Empty (7)	9.7	-
Nuculanidae (4)	5.6	6.2
Paguridae (3)	4.2	4.6
Plant (3)	4.2	4.6
Musculus niger (2)	2.8	3.1
Trochidae (2)	2.8	3.1
Crustacea (2)	2.8	3.1
Blue thread (2)	2.8	3.1
Hydrozoa (1)	1.4	1.5
Pectinariidae (1)	1.4	1.5
Nuculana sp. (1)	1.4	1.5
Thyasira sp. (1)	1.4	1.5
Psephidia lordi (1)	1.4	1.5
Polinices sp. (1)	1.4	1.5

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Stomachs with food
Amphipoda (1)	1.4	1.5
Pandalidae (1)	1.4	1.5
Unidentified material (1)	1.4	1.5
Pollutant (1)	1.4	1.5
Izhut Bay - 9-10 June 1978	N = 58	N = 56
Sediment (38)	66.1	67.9
Axinopsida serricata (33)	56.9	58.9
Unidentified animal material (31)	53.4	55.4
Pisces (28)	48.3	50.0
Pelecypoda (26)	44.8	46.4
Foraminifera (15)	25.9	26.8
Crustacea (12)	20.7	21.4
Decapoda (10)	17.2	17.9
Golden fiber (8)	13.8	14.3
Nucula tenuis (7)	12.1	12.5
Shrimp (6)	10.3	10.7
Gastropoda (5)	8.6	8.9
Macoma sp. (4)	6.9	7.1
Ophiuroidea (4)	6.9	7.1
Nucula fossa (3)	5.2	5.4
Chionoecetes bairdi (3)	5.2	5.4
Thread (blue, red, green) (3)	5.2	5.4
Unidentified plant material (2)	3.4	3.6
Sabellidae (2)	3.4	3.6
Empty (2)	3.4	-
Hydroid (1)	1.7	1.8
Polychaeta (1)	1.7	1.8
Cyclocardia sp. (1)	1.7	1.8
Transenella sp. (1)	1.7	1.8
Pectinidae (1)	1.7	1.8
Nuculanidae (1)	1.7	1.8
Clinocardium sp. (1)	1.7	1.8
Polyplacophora (1)	1.7	1.8
Amphipoda (1)	1.7	1.8
Paguridae (1)	1.7	1.8
Cucumaria sp. (1)	1.7	1.8
Echinodermata (1)	1.7	1.8

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Stomachs with food
Izhut Bay - 9-12 July 1978	N = 20	N = 20
Unidentified animal material (20)	100.0	100.0
Sediment (16)	80.0	80.0
Axinopsida serricata (12)	60.0	60.0
Golden fiber (9)	45.0	45.0
Foraminifera (5)	25.0	25.0
Pisces (5)	25.0	25.0
Chionoecetes bairdi (4)	20.0	20.0
Crustacea (3)	15.0	15.0
Crab (3)	15.0	15.0
Plant (1)	5.0	5.0
Pelecypoda (1)	5.0	5.0
Nuculanidae (1)	5.0	5.0
Decapoda (1)	5.0	5.0
Paguridae (1)	5.0	5.0
Pinnixa sp. (1)	5.0	5.0
Shrimp (1)	5.0	5.0
Echinodermata (1)	5.0	5.0
Echiuridae (1)	5.0	5.0
Ophiuridea (1)	5.0	5.0
Izhut Bay - 6-7 November 1978	N = 17	N = 16
Unidentified animal material (16)	94.1	100.0
Sediment (16)	94.1	100.0
Pisces (15)	88.2	93.8
Pelecypoda (11)	64.7	68.8
Ophiuridea (8)	47.1	50.0
Decapoda (5)	29.4	31.3
Pectinariidae (4)	23.5	25.0
Axinopsida serricata (4)	23.5	25.0
Blue thread (4)	23.5	25.0
Nucula tenuis (2)	11.8	12.5
Nuculana fossa (2)	11.8	12.5
Amphipoda (2)	11.8	12.5
Chionoecetes bairdi (2)	11.8	12.5
Cucumaria sp. (2)	11.8	12.5
Foraminifera (1)	5.9	6.3
Polychaeta (1)	5.9	6.3
Nuculanidae (1)	5.9	6.3

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs with food
Crab (1)	5.9	6.3
Shrimp (1)	5.9	6.3
Golden fiber (1)	5.9	6.3
Empty (1)	5.9	6.3
Izhut Bay - 5-18 March 1979	N = 20	N = 20
Unidentified animal material (19)	95.0	95.0
Sediment (17)	85.0	85.0
Pelecypoda (15)	75.0	75.0
Amphipoda (10)	50.0	50.0
Nuculanidae (7)	35.0	35.0
Pisces (6)	30.0	30.0
Golden fiber (5)	25.0	25.0
Axinopsida serricata (4)	20.0	20.0
Foraminifera (4)	20.0	20.0
Polychaeta (2)	10.0	10.0
Nuculana sp. (2)	10.0	10.0
Ophiuroidea (2)	10.0	10.0
Thread (2)	10.0	10.0
Nucula tenuis (1)	5.0	5.0
Alvinia sp. (1)	5.0	5.0
Solariella sp. (1)	5.0	5.0
Gastropoda (1)	5.0	5.0
Chionoecetes bairdi (1)	5.0	5.0
Crab (1)	5.0	5.0
Kiliuda Bay - 19-21 April 1978	N = 54	N = 53
Pelecypoda (43)	79.6	81.1
Unidentified animal material (40)	74.1	75.5
Sediment (28)	51.9	52.8
Polychaeta (18)	33.3	34.0
Decapoda (13)	24.1	24.5
Pisces (12)	22.2	22.6
Echinodermata (11)	20.4	20.8
Foraminifera (10)	18.5	18.9
Crustacea (10)	18.5	18.9
Nucula tenuis (7)	13.0	13.2
Plant (5)	9.3	9.4

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Percent Frequency of Occurrence Based on Stomachs with food
Psephidia lordi (4)	7.4	7.5
Cistenides sp. (3)	5.6	5.7
Amphiuridae (3)	5.6	5.7
Ophiuroidea (3)	5.6	5.7
Pollutants (3)	5.6	5.7
Axinopsida serricata (1)	1.9	1.9
Nuculana sp. (1)	1.9	1.9
Nuculanidae (1)	1.9	1.9
Velutina sp. (1)	1.9	1.9
Naticidae (1)	1.9	1.9
Gastropoda (1)	1.9	1.9
Copepoda (1)	1.9	1.9
Chionoecetes bairdi (1)	1.9	1.9
Ostracoda (1)	1.9	1.9
Empty (1)	1.9	-
Kiliuda Bay - 18-20 June 1978	N = 98	N = 89
Sediment (57)	58.2	64.0
Axinopsida serricata (51)	52.0	57.3
Spionidae (37)	37.8	41.6
Nucula tenuis (28)	28.6	31.5
Crab (20)	20.4	22.5
Foraminifera (14)	14.3	15.7
Pisces (10)	10.2	11.2
Empty (9)	9.2	-
Gastropoda (7)	7.1	7.9
Crustacea (7)	7.1	7.9
Macoma sp. (6)	6.1	6.7
Pelecypoda (6)	6.1	6.7
Plant (5)	5.1	5.6
Polychaeta (4)	4.1	4.5
Shrimp (4)	4.1	4.5
Unidentified animal material (4)	4.1	4.5
Echinodermata (3)	3.1	3.4
Polydora sp. (2)	2.0	2.2
Cylichna sp. (2)	2.0	2.2
Veneridae (2)	2.0	2.2
Balanus sp. (2)	2.0	2.2

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Stomachs with food
Decapoda (2)	2.0	2.2
Golden fiber (2)	2.0	2.2
Porifera (1)	1.0	1.1
Nuculana sp. (1)	1.0	1.1
Amphipoda (1)	1.0	1.1
Kiliuda Bay - 18-21 July 1978	N = 20	N = 16
Unidentified animal material (15)	75.0	93.8
Sediment (13)	65.0	81.3
Foraminifera (7)	35.0	43.8
Pinnixa sp. (4)	20.0	25.0
Empty (4)	20.0	-
Polynoidae (1)	5.0	6.3
Pelecypoda (1)	5.0	6.3
Nuculanidae (1)	5.0	6.3
Nuculana fossa (1)	5.0	6.3
Nucula tenuis (1)	5.0	6.3
Decapoda (1)	5.0	6.3
Chionoecetes bairdi (1)	5.0	6.3
Crab (1)	5.0	6.3
Shrimp (1)	5.0	6.3
Pisces (1)	5.0	6.3
Golden fiber (1)	5.0	6.3
Kiliuda Bay - 19-22 August 1978	N = 20	N = 19
Unidentified animal material (17)	85.0	89.5
Sediment (14)	70.0	73.7
Axinopsida serricata (10)	50.0	52.6
Foraminifera (7)	35.0	36.8
Nucula tenuis (7)	35.0	36.8
Chionoecetes bairdi (6)	30.0	31.6
Retusa sp. (5)	25.0	26.3
Ophiuridae (5)	25.0	26.3
Golden fiber (5)	25.0	26.3
Polychaeta (4)	20.0	21.1
Plant (3)	15.0	15.8
Nuculana fossa (3)	15.0	15.8
Crab (3)	15.0	15.8

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Stomachs with food
Pisces (3)	15.0	15.8
Nephtys sp. (2)	10.0	10.5
Nuculanidae (2)	10.0	10.5
Amphipoda (2)	10.0	10.5
Hydrozoa (1)	5.0	5.3
Pelecypoda (1)	5.0	5.3
Macoma sp. (1)	5.0	5.3
Gastropoda (1)	5.0	5.3
Gammaridae (1)	5.0	5.3
Shrimp (1)	5.0	5.3
Echiuridae (1)	5.0	5.3
Blue thread (1)	5.0	5.3
Empty (1)	5.0	-
Kiliuda Bay - 14-16 November 1978	N = 14	N = 14
Unidentified animal material (14)	100.0	100.0
Sediment (14)	100.0	100.0
Foraminifera (9)	64.3	64.3
Pelecypoda (8)	57.1	57.1
Pisces (7)	50.0	50.0
Axinopsida serricata (6)	42.9	42.9
Ophiuroidea (5)	35.7	35.7
Pectinariidae (3)	21.4	21.4
Golden fiber (3)	21.4	21.4
Nuculanidae (2)	14.3	14.3
Decapoda (2)	14.3	14.3
Shrimp (2)	14.3	14.3
Plant (1)	7.1	7.1
Hydrozoa (1)	7.1	7.1
Pinnixa sp. (1)	7.1	7.1
Blue thread (1)	7.1	7.1
Kiliuda Bay - 5-18 March 1979	N = 20	N = 19
Unidentified animal material (18)	90.0	94.7
Sediment (17)	85.0	89.5
Foraminifera (7)	35.0	36.8
Pisces (7)	35.0	36.8

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on Total Stomachs	Stomachs with food
Pelecypoda (5)	25.0	26.3
Crustacea (5)	25.0	15.8
Nucula tenuis (3)	15.0	15.8
Crab (3)	15.0	15.8
Hydrozoa (2)	10.0	10.5
Axinopsida serricata (2)	10.0	10.5
Chionoecetes bairdi (2)	10.0	10.5
Thread (2)	10.0	10.5
Plant (1)	5.0	5.3
Polychaeta (1)	5.0	5.3
Gastropoda (1)	5.0	5.3
Balanus sp. (1)	5.0	5.3
Ophiuroidea (1)	5.0	5.3
Golden fiber (1)	5.0	5.3
Empty (1)	5.0	-
Kodiak Shelf - 3-24 March 1978	N = 7	N = 7
Pelecypoda (4)	57.1	57.1
Scaphopoda (4)	57.1	57.1
Polychaeta (2)	28.6	28.6
Psephidia lordi (2)	28.6	28.6
Nucula tenuis (2)	28.6	28.6
Yoldia beringius (1)	14.3	14.3
Yoldia sp. (1)	14.3	14.3
Trochidae (1)	14.3	14.3
Gastropoda (1)	14.3	14.3
Ophiuridea (1)	14.3	14.3
Echinodermata (1)	14.3	14.3
Near Island Basin - 26, 30 October 1978	N = 49	N = 49
Unidentified animal material (48)	98.0	98.0
Sediment (38)	77.6	77.6
Lacuna variegata (30)	61.2	61.2
Pelecypoda (29)	59.2	59.2
Axinopsida serricata (28)	57.1	57.1
Amphipoda (15)	30.6	30.6
Oenopota sp. (9)	18.4	18.4
Teleostei (8)	16.3	16.3
Foraminifera (4)	8.2	8.2

APPENDIX B - TABLE II

CONTINUED

Stomach Contents	Percent Frequency of Occurrence Based on	
	Total Stomachs	Stomachs with food
Pinnixa occidentalis (3)	6.1	6.1
Cardiomya sp. (3)	6.1	6.1
Crangonidae (2)	4.1	4.1
Echinodermata (2)	4.1	4.1
Polychaeta (2)	4.1	4.1
Pollutant (blue thread) (2)	4.1	4.1
Chionoecetes bairdi (2)	4.1	4.1
Ophiuroidea (1)	2.0	2.0
Macoma sp. (1)	2.0	2.0
Echiuridae setae (1)	2.0	2.0

Appendix C - Summer Food of the Pacific Cod, *Gadus macrocephalus*, Near Kodiak Island, Alaska

SUMMER FOOD OF THE PACIFIC COD, *GADUS MACROCEPHALUS*, NEAR KODIAK ISLAND, ALASKA[1,2,3]

The Pacific cod, *Gadus macrocephalus* Tilesius, was the target of the earliest United States commercial fishery in the North Pacific (Buck[4]). Its fleet, organized in spring 1865 (Bean 1887), began to fish along the Alaska Peninsula and the Aleutian Islands and eventually expanded into the Bering Sea (Cobb 1916). Dwindling stocks and poor market prices ultimately resulted in the collapse of this fishery shortly after World War II (Ketchen 1961).

Growing pressures in recent years on domestic fishing stocks, in addition to increased worldwide protein demand, improved technological skills and readily available investment capital, have resulted in renewed interest in Pacific cod in the United States (Jones 1977). A bottomfish survey off the coast of Kodiak Island and throughout Shelikof Strait by the National Marine Fisheries Service in 1973 showed the Pacific cod to be one of the most abundant fishes inhabiting the area and the standing stock was conservatively estimated to be about 36,363 t (Hughes and Parks 1975). A small experimental trawl fishery for the Pacific cod and other bottom fishes has been proposed for the Kodiak region by Jones (1977).

Preliminary examination of *G. macrocephalus* stomach contents by Alaska Department of Fish and Game (ADF&G) biologist Guy C. Powell and the author during ADF&G crab investigations off Kodiak Island indicated a high frequency of occurrence of the commercially important snow crab, *Chionoecetes bairdi*. In view of the probable predation pressure on existing snow crab populations by *G. macrocephalus* and in view of the potential commercial importance of the Pacific cod, the summer food habits of this fish in the Kodiak area were examined by me. Ancillary goals included a comparison of food data from pot- and trawl-captured cod.

Methods

Specimens were taken near Kodiak Island, Alaska, (Figure 1) in conjunction with the crab-assessment studies of ADF&G and the surveys of the International Pacific Halibut Commission. Fishing gear consisted of commercial king crab pots, measuring 203 × 203 × 76 cm (inside) and weighing 340 kg; baited with chopped, frozen herring. Webbing was #72 tarred nylon thread with mesh stretched to 7.6 cm. The gear used on the halibut-survey vessels in July 1975 and July 1976 was a standard 400-mesh Eastern otter trawl (Greenwood 1958). Sampling by pots was from 26 June to 3 August 1973, 28 June to 31 July 1974, and 30 June to 27 July 1975. Stations usually consisted of 4-12 pots in a straight line, equally spaced every 0.46 km. Gear was pulled every 18-24 h except when weather conditions prolonged fishing time.

A haphazard sample of 3,933 of Pacific cod was taken from 10,857 cod caught in pots (the number sampled was contingent on the shipboard time available for analysis of stomach contents). Food items were identified to the lowest taxon practical aboard ship, and unidentifiable contents were preserved for later laboratory examination. Analysis of stomach contents was carried out using the frequency of occurrence method in which the prey organisms are expressed as the percent of stomachs containing various food items from the total number of stomachs analyzed. Cod were arbitrarily divided into 33-52 cm, 53-72 cm, and 73-92 cm size (total length) groups for analysis.

The frequency of occurrence method was also used for food data from trawl-caught Pacific cod. The stomachs of 344 cod were examined from 24 trawl stations, which were located in the same general area as the pot stations (Figure 1).

Results and Discussion

As determined from the pot data, the summer diet of *G. macrocephalus* was fishes, crabs, shrimps, and amphipods, in decreasing order of occurrence (Table 1). The most frequently occurring fish was walleye pollock, *Theragra chalcogramma*. Flatfishes (Pleuronectidae) and Pacific sand lance, *Ammodytes hexapterus*, were also frequent. Suyehiro (1942:233-236), Moiseev (1953, 1960), and Mito (1974) also reported that Pacific cod feed on these fishes.

---

[1] Contribution No. 339, Institute of Marine Science, University of Alaska, Fairbanks, AK 99701.

[2] This study was partially supported under contract 03-5-022-56 between the University of Alaska and NOAA, U.S. Department of Commerce through the Outer Continental Shelf Environmental Assessment Program to which funds were provided by the Bureau of Land Management, U.S. Department of Interior.

[3] Based on a thesis submitted in partial fulfillment of the requirements for the M.S. degree, University of Alaska.

[4] Buck, E. H. 1973. Alaska and the law of the sea. National patterns and trends of fishery development on the North Pacific. Alaska Sea Grant Rep. No. 73-4, 65 p.

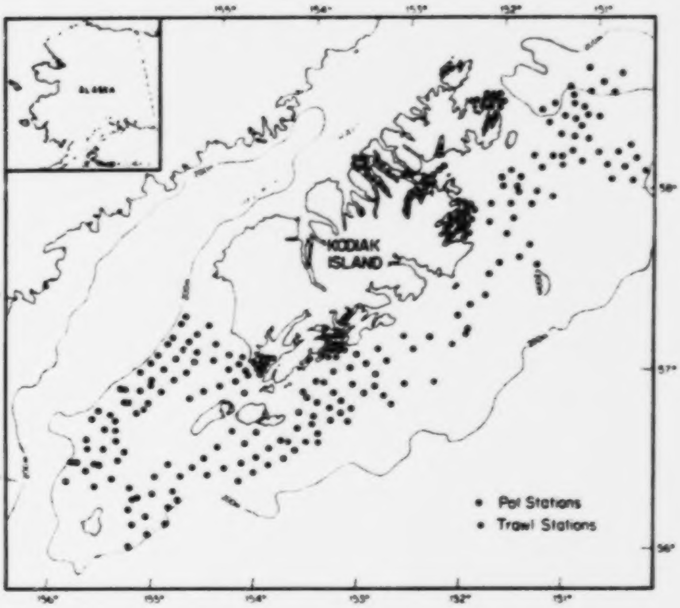


FIGURE 1.—Stations near Kodiak Island, Alaska, where Pacific cod were collected by pots and trawls during summers of 1973-75.

Crab occurrences were dominated by juvenile *C. bairdi*. Snow crabs were the single most frequently occurring food species found in Pacific cod stomachs and occurred in nearly 40% of the cod (Table 2). The average number of snow crabs occurring in cod feeding on snow crabs was 3.3 and they ranged from 1.8 to 70 mm carapace width[5] (Hilsinger et al.[6]); 78% were between 7 and 23 mm. Up to 32 crabs were found in a single cod stomach.

Chionoecetes bairdi had become important in the Alaskan and world markets with landings for Kodiak increasing from 50.3 t in 1967 to 12,400 t in 1976 (North Pacific Fishery Management Council[7]). Since juvenile snow crabs are a major item in the diet of the Pacific cod, reduction of cod stocks by the anticipated new bottomfish fishery should improve the chances for survival of young crabs. Enhanced recruitment of snow crabs to fishable stocks might result from such improved survival.

Pandalid and crangonid shrimps were important in the diet of the Pacific cod in the Kodiak area, a region where both groups are abundant in species and numbers (Ronholt 1963; Barr 1970; Feder and Jewett[8]).

Anonyx nugax may be the principal amphipod. Amphipods which were occasionally preserved from the stomach contents as well as from the perforated bait cans in the crab pots were later identified as *A. nugax*. Because of attraction to the bait, the occurrence of amphipods in stomachs of the pot-caught cod was probably artificially high.

Occurrence of food organisms in trawl-caught cod, in decreasing order was also fishes, crabs, shrimps, and amphipods (Table 3). The most common fishes were *A. hexapterus*, *T. chalcogramma*, and flatfishes. The most frequently consumed crab was *C. bairdi*. Shrimps were primarily Crangonidae.

Wilcoxon's paired-sample test indicated no significant difference ($\alpha = 0.05$) among food groups from cod caught by the two methods, or between sexes (Table 4). No sex differences were found in

---

[5] Females mature at about 72 mm carapace width (Hilsinger et al. see footnote 6) and males at about 110 mm carapace width (Brown and Powell 1972).

[6] Hilsinger, J. R., W. E. Donaldson, and R. T. Cooney. 1975. The Alaska snow crab, *Chionoecetes bairdi*, size and growth. Unpubl. manuscr., 38 p. Univ. Alaska Sea Grant Rep. No. 75-12 (Inst. Mar. Sci. Rep. No. 75-6).

[7] Fishery Management Plan and environmental impact statement for the tanner crab off Alaska. Sept. 23, 1977. Unpubl. manuscr., 346 p., prepared by the North Pac. Fish. Manage. Counc.

[8] Feder, H. M., and S. C. Jewett. 1977. The distribution, abundance, and diversity of the epifauna of two bays (Alitak and Ugak) of Kodiak Island, Alaska. Inst. Mar. Sci. [Univ. Alaska] Rep. R77-3, 74 p.

TABLE 1.—Frequency and percent frequency of occurrence of summer food items in stomachs of *Gadus macrocephalus* collected during 1973-75 by pots near Kodiak Island, Alaska. N = number of stomachs examined. Subtotals in parentheses.

FOOD ITEMS	1973 N=689 Freq.	1973 N=689 % Freq.	1974 N=1183 Freq.	1974 N=1183 % Freq.	1975 N=2061 Freq.	1975 N=2061 % Freq.	TOTAL 1973-75 N=3933 Freq.	TOTAL 1973-75 N=3933 % Freq.
Coelenterata								
Hydrozoa (hydroids)	2	0.3	-	-	1	0.1	3	0.08
Scyphozoa (jellyfishes)	-	-	-	-	1	0.1	1	0.03
Anthozoa (anemones)	5	0.7 (1.0)	3	0.3	1	0.1 (0.3)	9	0.2 (0.31)
Annelida								
Polychaeta (segmented worms)	-	-	53	4.5	74	3.6	127	3.2
Aphrodita sp.	15	2.1	10	0.9 (5.4)	24	1.2 (4.8)	49	1.2 (4.4)
Mollusca								
Polyplacophora (chitons)	-	-	1	0.1	-	-	1	0.03
Pelecypoda (clams, mussels, cockles)								
Astarte polaris	-	-	1	0.1	1	0.1	2	0.05
Chlamys sp.	-	-	-	-	1	0.1	1	0.03
Clinocardium sp.	1	0.1	-	-	4	0.2	5	0.1
Cyclocardia crassidens	1	0.1	1	0.1	1	0.1	3	0.08
Cyclocardia crebricostata	1	-	1	0.1	-	-	1	0.03
Cyclocardia sp.	-	-	-	-	2	0.1	2	0.05
Glycymeris subobsoleta	1	0.1	-	-	-	-	1	0.03
Hiatella arctica	1	0.1	-	-	-	-	1	0.03
Limopsis akutanica	-	-	1	0.1	-	-	1	0.03
Limopsis vaginatus	-	-	2	0.2	-	-	2	0.05
Macoma brota	-	-	-	-	1	0.1	1	0.03
Macoma calcarea	-	-	-	-	1	0.1	1	0.03
Macoma expansa	1	0.1	-	-	-	-	1	0.03
Macoma moesta	-	-	1	0.1	1	0.1	2	0.05
Macoma sp.	1	0.1	1	0.1	1	0.1	3	0.08
Modiolus sp.	-	-	-	-	2	0.1	2	0.05
Musculus discors	-	-	-	-	1	0.1	1	0.03
Musculus olivaceus	1	0.1	1	0.1	1	0.1	3	0.08
Nucula tenuis	1	0.1	-	-	4	0.2	5	0.1
Nuculana fossa	30	4.3	43	3.6	36	1.8	109	2.7
Panomya ampla	1	0.1	-	-	-	-	1	0.03
Patinopecten caurinus	-	-	7	0.6	5	0.2	12	0.3
Pododesmus macroschisma	-	-	1	0.1	1	0.1	2	0.05
Psephidia lordi	1	0.1	-	-	-	-	1	0.03
Puncturella galeata	-	-	1	0.1	-	-	1	0.03
Serripes groenlandicus	-	-	3	0.3	3	0.1	6	0.1
Siliqua sloati	-	-	-	-	1	0.1	1	0.03
Tellina nuculoides	-	-	-	-	1	0.1	1	0.03
Velutina velutina	1	0.1	-	-	-	-	1	0.03
Yoldia beringiana	2	0.3	-	-	5	0.2	7	0.2
Yoldia myalis	-	-	2	0.2	-	-	2	0.05
Yoldia thraciaeformis	-	-	1	0.1	-	-	1	0.03
Yoldia sp.	7	1.0	4	0.3	-	-	12	0.3
Unidentified Pelecypods	26	3.8	27	2.3	53	2.6	106	2.7
Gastropods (snails)								
Admete couthouyi	-	-	-	-	1	0.1	1	0.03
Aforia circinata	-	-	-	-	1	0.1	1	0.03
Amphissa columbiana	1	0.1	-	-	1	0.1	2	0.05
Beringius kennicotti	-	-	-	-	1	0.1	1	0.03
Boreotrophon pacifica	-	-	1	0.1	1	0.1	2	0.05
Buccinum sp.	1	0.1	-	-	-	-	1	0.01
Colus halli	-	-	-	-	2	0.1	2	0.05
Cylichna alba	1	0.1	1	0.1	-	-	2	0.05
Fusitriton oregonensis	1	0.1	-	-	2	0.1	3	0.08
Margarites baxter	-	-	1	0.1	-	-	1	0.03
Margarites obscura	-	-	1	0.1	2	0.1	3	0.08
Margarites pupillus	-	-	-	-	1	0.1	1	0.03
Mitrella gouldi	-	-	-	-	1	0.1	1	0.03
Natica aleutica	1	0.1	2	0.2	-	-	3	0.08
Natica clausa	-	-	1	0.1	-	-	1	0.03
Natica sp.	-	-	-	-	5	0.2	5	0.1
Neptunea sp.	1	0.1	-	-	1	0.1	2	0.05
Polinices nanus	-	-	-	-	1	0.1	1	0.03
Polinices pallida	2	0.3	2	0.2	3	0.2	7	0.2
Solariella varicosa	-	-	1	0.1	-	-	1	0.03
Tachyrhynchus sp.	-	-	1	0.1	-	-	1	0.03
Trichotropis cancellata	1	0.1	1	0.1	3	0.2	5	0.01
Turridae	-	-	-	-	1	0.1	1	0.03
Unidentified gastropods	1	0.1 (11.6)	26	2.2 (11.9)	34	1.7 (10.3)	61	1.5 (10.2)
Cephalopoda								
Octopi	53	7.6	108	9.1	164	8.0	326	8.3
Squid	-	-	1	0.1 (9.2)	-	-	-	-
Arthropoda								
Crustacea								

TABLE 1.—Continued.

FOOD ITEMS	1973 N=689 Freq.	1973 % Freq.	1974 N=1183 Freq.	1974 % Freq.	1975 N=2061 Freq.	1975 % Freq.	TOTAL 1973-75 N=3933 Freq.	TOTAL 1973-75 % Freq.
Malacostraca								
Euphausiacea (krill) and Mysidacea (mysids)	20	2.9	34	2.9	181	8.8	235	6.0
Isopoda (pill bugs)	3	0.4	4	0.3	10	0.5	17	0.4
Amphipoda (sand fleas)	192	27.8	195	16.5	407	19.8	794	20.2
Ampelisca macrocephala	-	-	-	-	52	2.5 (22.3)	52	1.3 (21.5)
Decapoda								
Pandalidae (shrimps)	67	9.7	118	10.0	-	-	185	4.7
Pandalus borealis	-	-	-	-	166	8.1	166	4.2
Pandalopsis dispar	-	-	4	0.3	19	0.9	23	0.6
Pandalus goniurus	-	-	-	-	4	0.2	4	0.1
Pandalus hypsinotus	-	-	-	-	7	0.3	7	0.2
Pandalus montagui tridens	-	-	-	-	8	0.4	8	0.2
Pandalus platyceros	-	-	1	0.1	3	0.2	4	0.1
Crangonidae (shrimps)	77	11.1	95	8.0	286	13.9	458	11.6
Argis crassa	-	-	-	-	3	0.2	3	0.08
Sclerocrangon boreas	-	-	-	-	5	0.2	5	0.1
Hippolytidae								
Spirontocaris **sp.**	-	-	-	-	5	0.2	5	0.1
Unidentified shrimps	131	19.0 (39.8)	82	6.9 (25.3)	171	8.3 (32.9)	384	9.8 (31.8)
Paguridae (hermit crabs)	24	3.4	21	1.8	55	2.7	100	2.5
Elassochirus cavimanus	-	-	-	-	2	0.1	2	0.05
Elassochirus tenuimanus	-	-	1	0.1	3	0.2	4	0.1
Lithodidae (crabs)								
Paralithodes camtschatica	2	0.3	9	0.8	31	1.5	42	1.1
Placetron wosnessenskii	-	-	1	0.1	2	0.1	3	0.08
Rhinolithodes wosnessenskii	-	-	-	-	1	0.1	1	0.03
Galatheidae (crabs)								
Munida quadrispina	-	-	-	-	1	0.1	1	0.03
Cancridae (crabs)	-	-	1	0.1	13	0.6	16	0.4
Cancer sp.	4	0.5	-	-	-	-	4	0.1
Telmessus cheiragonus	1	0.1	-	-	2	0.1	3	0.08
Pinnotheridae (pea crabs)								
Pinnixa sp.	5	0.7	36	3.0	23	1.1	64	1.6
Majidae (spider crabs)								
Chionoecetes bairdi	281	40.7	428	36.2	735	35.6	1444	36.7
Hyas lyratus	13	1.8	44	3.7	42	2.0	99	2.5
Oregonia gracilis	-	-	3	0.3	6	0.3	9	0.2
Unidentified crabs	12	1.7 (49.2)	3	0.3 (46.4)	4	0.2 (44.7)	19	0.5 (46.0)
Echinodermata								
Asteroidea (sea stars)	1	0.1	2	0.2	1	0.1	4	0.1
Ctenodiscus crispatus	-	-	-	-	1	0.1	1	0.03
Echinoidea (sea urchins)	1	0.1	-	-	1	0.1	2	0.05
Holothuroidea (sea cucumbers)	2	0.3	5	0.4	10	0.5	17	0.4
Ophiuroidea (brittle stars)	-	-	3	0.3	3	0.2	6	0.1
Ophiura sarsi	-	- (0.4)	-	- (0.9)	2	0.1 (1.1)	2	0.05 (0.73)
Vertebrata								
Osteichthyes								
Clupeidae (herrings)								
Clupea harengus pallasi	6	0.8	1	0.1	2	0.1	9	0.2
Osmeridae (smelts)	3	0.4	2	0.2	4	0.2	9	0.2
Mallotus villosus	-	-	-	-	1	0.1	1	0.03
Gadidae (codfishes)								
Theragra chalcogramma	12	1.7	32	2.7	109	5.3	153	3.9
Gadus macrocephalus	7	1.0	13	0.9	3	0.2	23	0.6
Zoarcidae (eelpouts)	29	4.2	9	0.8	7	0.3	45	1.1
Lycodes brevipes	-	-	-	-	3	0.2	3	0.08
Scorpaenidae (rockfishes)	1	0.1	1	0.1	-	-	2	0.05
Hexigrammidae (greenlings)								
Pleurogrammus monopterigius	-	-	-	-	2	0.1	2	0.05
Cottidae (bullheads)	8	1.1	27	2.3	6	0.3	41	1.0
Dasycottus setiger	-	-	-	-	2	0.1	2	0.05
Hemilepidotus jordani	-	-	-	-	1	0.1	1	0.03
Gymnocanthus sp.	-	-	-	-	6	0.3	6	0.1
Agonidae (poachers)	-	-	3	0.3	17	0.8	20	0.5
Bathymasteridae (ronquils)								
Bathymaster signatus	-	-	1	0.1	2	0.1	3	0.05
Trichodontidae (sandfishes)								
Trichodon trichodon	-	-	4	0.3	2	0.1	6	0.1
Cyclopteridae (lumpsuckers)	1	0.1	1	0.1	5	0.2	7	0.2
Pleuronectidae (flatfishes)	22	3.2	21	1.8	40	1.9	83	2.1
Atheresthes stomias	-	-	-	-	2	0.1	2	0.05
Hippoglossoides elassodon	-	-	-	-	12	0.6	12	0.3
Hippoglossus stenolepis	-	-	-	-	2	0.1	2	0.05
Ammodytidae (sand lances)								
Ammodytes hexapterus	20	2.9	20	1.7	9	0.4	49	1.2
Stichaeidae (pricklebacks)	14	2.0	-	-	10	0.5	24	0.6
Crypacanthodidae (wrymouths)								
Lyconectes aleutensis	9	1.3	4	0.3	4	0.2	17	0.4
Unidentified fishes	256	37.1 (55.9)	476	40.2 (51.9)	655	31.8 (44.1)	1387	35.3 (48.2)
Stomachs empty	8	1.6	59	5.0	184	8.9	251	6.4

TABLE 2.—The importance of the snow crab, *Chionoecetes bairdi*, in the summer diet of Pacific cod. Analysis based on specimens from pots. Crab incidence is given for total number of cod examined; incidence as a percent of feeding cod given in parentheses.

Samping date	Cod examined (no.)	Feeding cod (%)	Incidence of crabs		Crabs (no.)	Average crab occurrence in cod feeding on crabs
			Number	Percent		
26 June-3 August 1973	689	98.8	281	40.7 (41.3)	1,022	3.6
28 June-31 July 1974	1,183	95.0	427	36.2 (38.0)	1,033	2.4
30 June-27 July 1975	2,061	91.0	734	35.6 (39.1)	2,682	3.6
Total	3,933	93.6	1,442	36.7 (39.2)	4,737	3.3

TABLE 3.—Frequency and percent frequency of occurrence of food items in stomachs of *Gadus macrocephalus* collected July 1975 and 1976 by otter trawl near Kodiak Island, Alaska. N = number of stomachs examined. Subtotals in parentheses.

Food items	July 1975 N = 150		July 1976 N = 194		Total 1975-1976 N = 344	
	Freq.	% Freq.	Freq.	% Freq.	Freq.	% Freq.
Annelida						
Polychaeta	2	1.3	3	1.5	5	1.4
Mollusca						
Pelecypoda and Gastropoda	17	11.3	10	5.1	27	7.8
Cephalopoda	3	2.0	8	4.1	11	3.2
Arthropoda						
Crustacea						
Euphausiacea and Mysidacea	13	8.6	10	5.1	23	6.7
Isopoda	-	-	3	1.5	3	0.9
Amphipoda	14	9.3	15	7.7	29	8.4
Decapoda						
Pandalidae	16	10.7	24	12.4	40	11.6
Crangonidae	37	24.7	37	19.1	74	21.5
Unidentified shrimps	18	12.0 (47.4)	24	12.4 (43.9)	42	12.2 (45.3)
Majidae						
Chionoecetes bairdi	55	36.7	82	42.3	137	39.8
Unidentified crabs	13	8.7 (45.4)	23	11.9 (54.2)	36	10.5 (50.3)
Echinodermata	1	0.6	-	-	1	0.3
Vertebrata						
Osteichthyes						
Gadidae						
Theragra chalcogramma	6	4.0	7	3.6	13	3.8
Pleuronectidae	5	3.3	4	2.1	9	2.6
Ammodytidae						
Ammodytes hexapterus	20	13.3	13	6.7	33	9.6
Unidentified fishes	66	44.0 (64.6)	70	36.1 (48.5)	136	39.5 (55.5)
Stomachs empty	7	4.7	13	6.7	20	5.8

TABLE 4.—Comparison of percent frequency of occurrence of summer food groups in male and female *Gadus macrocephalus* caught by pots and trawls in the Kodiak Island area.

Food groups	Percent frequency of occurrence in:			
	Pot-caught cod		Trawl-caught cod	
	Males	Females	Males	Females
Fishes	21.8	24.2	26.3	24.8
Crabs	22.0	19.3	24.2	20.9
Shrimps	15.1	14.2	15.4	24.7
Amphipods	10.0	14.3	4.1	4.3
Gastropods and pelecypods	5.0	4.7	3.3	4.5
Cephalopods	3.6	4.7	2.3	0.9
Euphausiids and mysids	2.1	4.0	4.0	2.7
Polychaetous annelids	1.4	3.1	0.3	1.1
Echinoderms	0.4	0.4	0.1	0.2
Isopods	0.2	0.2	0.5	0.4
Empty stomachs	4.4	2.0	2.8	3.0
Stomachs examined (no.)	2,106	1,827	188	156

other studies on Gadiformes (e.g., Homans and Vladykov 1954; Wigley 1956; Powles 1958; Wigley and Theroux 1965).

A significant difference (χ^2, $\alpha = 0.05$) was found for occurrence of food groups between years for each size group (Figure 2). The only similarity was among 33-52 cm fish between 1973 and 1975 and among 73-92 cm fish between 1974 and 1975. Some trends in frequency of food groups by cod size were apparent (Figure 2). Fishes and cephalopods increased in frequency with increasing cod size over all years while amphipods and polychaete worms decreased. Daan (1973) investigated the relative size of food items (crustaceans and fishes) used by the Atlantic cod, *G. morhua*, and found

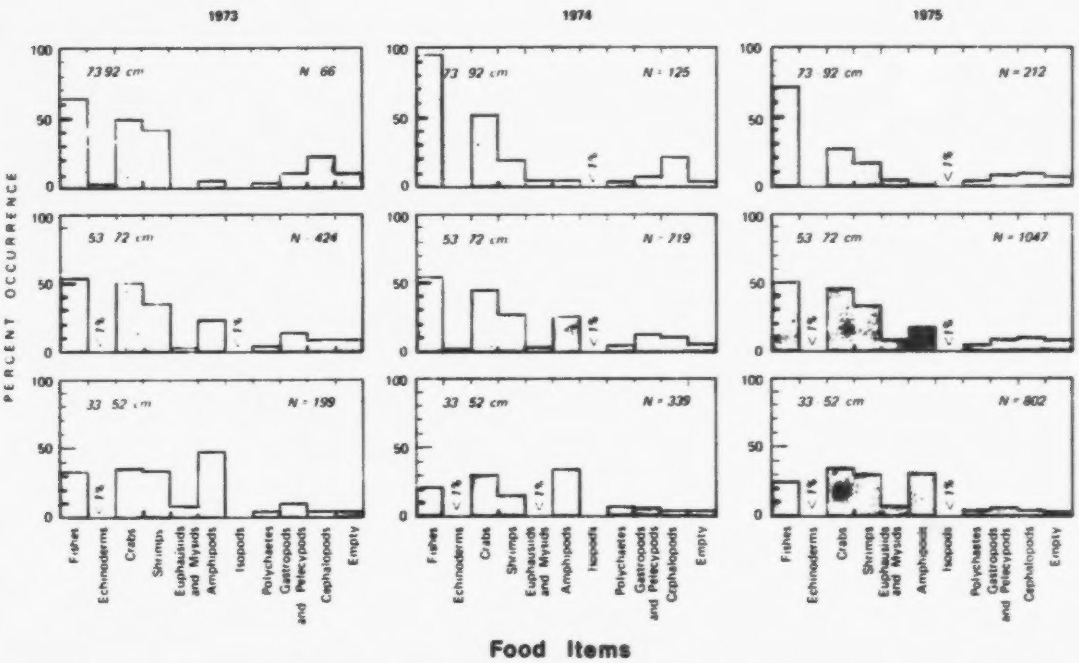


FIGURE 2.—Percent frequency of occurrence of summer food items within three size groups of pot-caught Pacific cod by year of collection—1973-75—near Kodiak Island, Alaska.

that smaller crustaceans were more commonly found in small cod while a gradual shift to a mixed diet of larger prey (primarily fishes) was noted for the larger fish. Arntz (1974) examined juvenile *G. morhua*, and found the most important food to be small crustaceans, mainly cumaceans (35.6% by weight of the total food consumed); fishes accounted for only 15.3% by weight of the total food consumed. This trend of large cod being more piscivorous than small cod has also been demonstrated by Powles (1958) and Rae (1967).

Acknowledgments

I am especially indebted to the ADF&G and Guy C. Powell for their assistance in collection of data. Special thanks to Howard M. Feder, University of Alaska, for his editing suggestions. Thanks to John R. Hilsinger, University of Alaska, for allowing me to use his Pacific cod feeding data obtained during International Pacific Halibut Commission surveys, and to George Mueller and Kenneth Vogt, both of the Marine Sorting Center, University of Alaska, for their taxonomic assistance. Mollusc identifications were made by Rae Baxter, ADF&G.

Literature Cited

ARNTZ, W. E.
1974. The food of juvenile cod (*Gadus morhua* L.) in Kiel Bay. [In Germ., Engl. summ.] Ber. dtsch. wiss. Komm. Meeresforsch. 23:97-120.

BARR, L.
1970. Alaska's fishery resources—the shrimps. U.S. Fish Wildl. Serv., Fish. Leafl. 631, 10 p.

BEAN, T. H.
1887. The cod fishery of Alaska. *In* G. B. Goode and staff of associates, Fishery and fishery industries of the United States, Sec. V. Vol. 1, p. 198-226. Wash.

BROWN, R. B., AND G. C. POWELL.
1972. Size at maturity in the male Alaskan tanner crab, *Chionoecetes bairdi*, as determined by chela allometry, reproductive tract weights, and size of precopulatory males. J. Fish. Res. Board Can. 29:423-427.

COBB, J. N.
1916. Pacific cod fisheries. Rep. U.S. Comm. Fish., 1915, append. 4, 111 p. (Doc. 830.)

DAAN, N.
1973. A quantitative analysis of the food intake of North Sea cod, *Gadus morhua*. Neth. J. Sea Res. 6:479-517.

GREENWOOD, M. R.
1958. Bottom trawling explorations of southeastern Alaska, 1956-1957. Commer. Fish. Rev. 20(12):9-21.

HOMANS, R. E. S., AND V. D. VLADYKOV.
1954. Relation between feeding and the sexual cycle of the haddock. J. Fish. Res. Board Can. 11:535-542.

HUGHES, S. E., AND N. B. PARKS.
1975. A major fishery for Alaska. Natl. Fisherman 55(13):34-40

JONES, W. G.
1977. Emerging bottomfish fisheries - potential effects. Alaska Seas Coasts 5:1-5.

KETCHEN, K. S.
1961. Observations on the ecology of the Pacific cod (*Gadus macrocephalus*) in Canadian waters. J. Fish. Res. Board Can. 18:513-558.

MITO, K.
1974. Food relation in demersal fishing community in the Bering Sea - walleye pollock fishing ground in October and November 1972. Master's Thesis, Hokkaido Univ., Hakodate, 86 p.

MOISEEV, P. A.
1953. [Cod and flounders of far-eastern waters.] Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 40:1-287. (Tranl. 1956, Fish Res. Board Can. Transl. Ser. 119, 576 p.)
1960. On the habits of the cod-fish *Gadus morhua macrocephalus* Tilesius in different zoogeographical regions. [In Russ., Engl. summ.] Zool. Zh. 39:558-562.

POWLES, P. M.
1958. Studies of reproduction and feeding of Atlantic cod (*Gadus callarias* L.) in the southwestern Gulf of St. Lawrence. J. Fish. Res. Board Can. 15:1383-1402.

RAE, B. B.
1967. The food of cod in the North Sea and on the west of Scotland grounds. Dep. Agric. Fish. Scotl, Mar. Res. 1967(1), 68 p.

RONHOLT, L. L.
1963. Distribution and relative abundance of commercially important pandalid shrimps in the northeastern Pacific Ocean. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 449, 28 p.

SUYEHIRO, Y.
1942. A study on the digestive system and feeding habits of fish. Jpn. J. Zool. 10:1-303.

WIGLEY, R. L.
1956. Food habits of Georges Bank haddock. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish 165, 26 p.

WIGLEY, R. L., AND R. B. THEROUX.
1965. Seasonal food habits of Higlands Ground haddock. Trans. Am. Fish. Soc. 94:243-251.

STEPHEN C. JEWETT

Institute of Marine Science
University of Alaska
Fairbanks, AK 99701

Appendix D - Summer Food of the Sculpins, *Myoxocephalus* spp. and *Hemilepidotus jordani*, Near Kodiak Island, Alaska

MARINE SCIENCE COMMUNICATIONS, 5(4&5), 315-331 (1979)

SUMMER FOOD OF THE SCULPINS, *MYOXOCEPHALUS* SPP. AND *HEMILEPIDOTUS JORDANI*, NEAR KODIAK ISLAND, ALASKA

Stephen C. Jewett

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

Guy C. Powell

Alaska Department of Fish and Game
Kodiak, Alaska 99615

Key Words: Trophic Relationships; Benthic Ecology.

ABSTRACT

Crabs were the dominant food, in terms of frequency of occurrence, of the sculpins, *Myoxocephalus* spp. and *Hemilepidotus jordani*, from the Kodiak, Alaska continental shelf. Major prey items of *Myoxocephalus* spp. were the crabs, *Chionoecetes bairdi* and *Hyas lyratus* and fishes. Major prey items consumed by *H. jordani* were also *C. bairdi* and *H. lyratus*, in addition to another crab, *Oregonia gracilis*.

Contribution No. 387, Institute of Marine Science, University of Alaska.

Copyright © 1979 by Marcel Dekker, Inc. All Rights Reserved. Neither this work nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage and retrieval system, without permission in writing from the publisher.

INTRODUCTION

The operations connected with oil exploration, production, and transportation in the Gulf of Alaska present a wide spectrum of potential dangers to the marine environment. Adverse effects of the environment cannot be assessed, or even predicted, unless background data are recorded prior to industrial development. Knowledge of marine trophic relationships is especially needed in view of probable petroleum development and expanding commercial fisheries in the Gulf. Recent studies in Alaska have partially focused on marine food webs (Feder and Jewett, 1976, 1977, 1978, in press; Jewett and Feder, in press; Lowry *et al.*, in press; Paul *et al.*, in press; Smith *et al.*, 1978).

Sculpin (Cottidae) populations are an integral part of the biological community of the Kodiak continental shelf. The sculpins, *Myoxocephalus* spp. and *Hemilepidotus* spp., currently make up approximately 10% of Kodiak's bottomfish bait production (Phillip Rigby, personal communication, Alaska Department of Fish and Game [ADF&G]), and are captured incidentally during bottomfish trawling. In recent months, demand for bottomfish resources in the Kodiak Island area for bait, as well as for human consumption, has increased, and is expected to grow rapidly in the near future (Pennington, 1978). Bottomfishes such as sculpins make excellent bait for king (*Paralithodes camtschatica*) and snow crabs (*Chionoecetes bairdi*).

Initial examination of the stomach contents of Pacific cod (*Gadus macrocephalus*) and sculpins (*Myoxocephalus* spp.* and *Hemilepidotus jordani*) in June 1973 revealed that young individuals of the commercially important snow crab were frequently preyed upon. In view of this predation upon snow crab populations, studies of the food habits of these fishes were continued.

Summer food of *Myoxocephalus* spp. and *Hemilepidotus jordani* near Kodiak Island, Alaska is described in this paper. Feeding data for Pacific cod (Jewett, 1978), also primarily a benthic feeder, were collected simultaneously with sculpin data and are, in part, included here for comparison.

METHODS

Sculpins were caught incidentally on the Kodiak Island continental shelf (Fig. 1) during ADF&G crab population studies. Fishes were captured in modified commercial king crab pots (Jewett, 1978), baited with chopped, frozen herring. Sampling occurred during

---

*Due to the difficulties in identification of *Myoxocephalus* to species, all species, mainly *M. polyacanthocephalus* and *M. joak*, were combined (Doyle Kessler, National Marine Fishery Service, Kodiak, Alaska, personal communication, 1978.

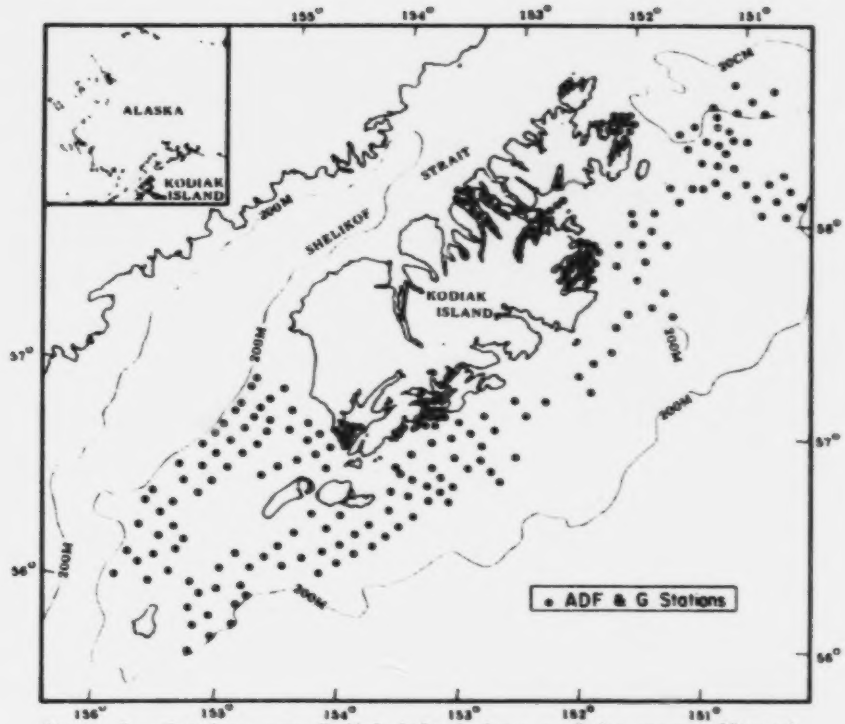

155°
154°
153°
152°
151°
ALASKA
KODIAK ISLAND
200M
SHELIKOF STRAIT
KODIAK ISLAND
200M
200M
200M
200M
200M
57°
56°
58°
57°
56°
• ADF & G Stations
156°
155°
154°
153°
152°
151°

Figure 1. Stations near Kodiak Island where sculpins were collected for stomach analysis during the summers of 1973-75.

FIG. 1. Stations near Kodiak Island where sculpins were collected for stomach analysis during the summers of 1973-75.

three summers; June 26 - August 3, 1973, June 28 - July 31, 1974, and June 30 - July 27, 1975. Stations consisted of 4-12 pots in a straight line, equally spaced every 0.46 km. Gear was pulled every 18 to 24 hours except when weather conditions prolonged fishing time.

The number of fish examined was contingent on shipboard time available for stomach analysis. Food items were identified to the lowest taxon practical aboard ship, and unidentifiable contents often were preserved for later laboratory examination. Similar food items were combined into food groups for comparison (Fig. 2). Occurrence of prey organisms is primarily expressed as the percent of total stomachs examined. The prey, *Chionoecetes bairdi*, was counted, sexed, and measured when possible. Maturity of female *C. bairdi* was noted only in 1975.

RESULTS

A sample of 855 sculpin stomachs (320 *Myoxocephalus* spp. and 535 *Hemilepidotus jordani*) were examined (Table I). The mean and range of the total lengths of *Myoxocephalus* spp. and *Hemilepidotus jordani* were 58 cm, 36-72 cm, and 34 cm, 23-41 cm respectively. The effect of size on the composition of diets was not noted.

No significant differences (χ^2, $\alpha = 0.05$) occurred between years for food groups used by *Myoxocephalus* spp. or *Hemilepidotus jordani* (Table I, Fig. 2).

Myoxocephalus spp.

Based on all fish examined, the dominant food groups of *Myoxocephalus* were crabs (59.4%) and fishes

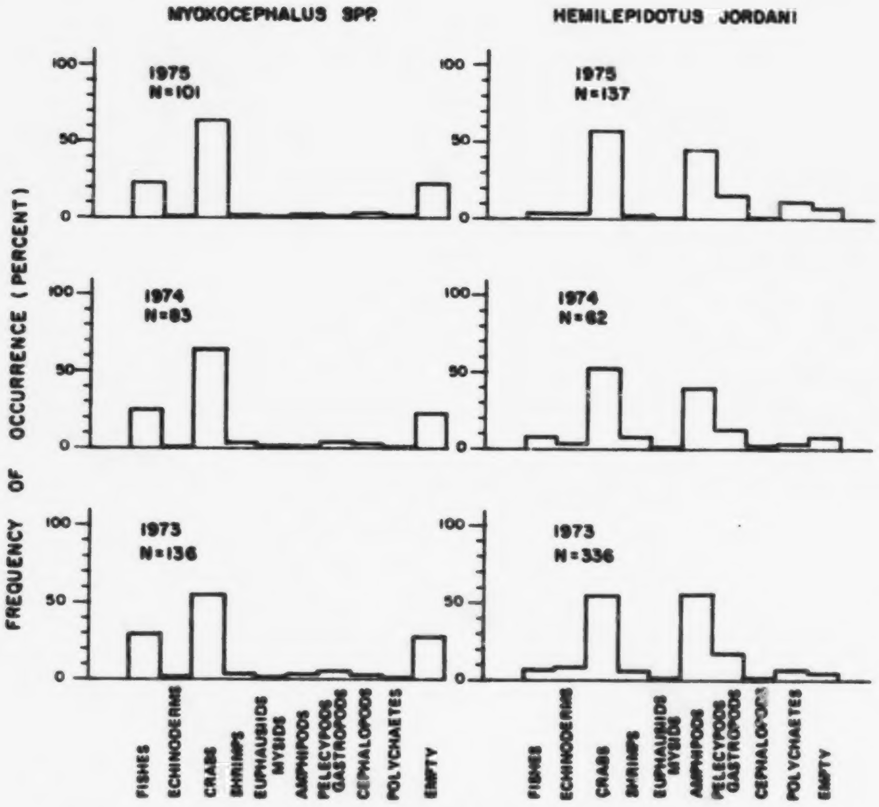


FIG. 2. Comparison of diets between two groups of sculpins collected during three summers near Kodiak Island.

(30.6%), with the crab, *Chionoecetes bairdi*, the most frequent species (39.1%) and the cottids the most frequent fishes (8.4%) (Table I). Other prey items are listed in Table I. Twenty-five percent of all *Myoxocephalus* examined were empty. The incidence of snow

TABLE I

Percent Frequency of Occurrence of Summer Food Items in Stomachs of *Myoxocephalus* spp. (M) and *Hemilepidotus jordani* (HJ) Collected Near Kodiak Island, Alaska. N = Number of Stomachs Examined. Subtotals in Parentheses Indicate the Percent Occurrence of a Particular Food Group; Food Items Within a Group are not Necessarily Additive.

	1973		1974		1975		1973-75	
FOOD ITEMS	M N=136	HJ N=336	M N=83	HJ N=62	M N=101	M N=137	M N=320	HJ N=535
Coelenterata								
Anthozoa (anemones)	-	2.1	-	1.6	-	-	-	1.5
Annelida								
Polychaeta (segmented worms)								
Aphrodita sp.	-	0.3	-	-	1.0	2.2	0.3	0.7
Unidentified polychaetes	0.7	6.8 (7.4)	-	3.2	-	8.8 (10.9)	0.3 (0.3)	6.9 (7.9)
Mollusca								
Amphineura (chitons)	-	0.3	-	-	-	-	-	0.2
Pelecypoda (clams, mussels, cockles)								
Axinopsida serricata	-	0.3	-	-	-	-	-	0.2
Cyclocardia crassidens	-	0.3	-	-	-	-	-	0.2
Hiatella arctica	-	0.3	-	-	-	-	-	0.2
Macoma sp.	-	0.6	-	-	-	-	-	0.4
Musculus olivaceus	-	0.6	-	-	-	-	-	0.4
Musculus sp.	-	-	-	-	-	0.7	-	0.2
Mytilus edulis	0.7	-	-	-	-	0.7	0.3	0.2
Nuculana fossa	-	-	-	-	-	0.7	-	0.2
Chlamys sp.	-	0.3	-	-	-	-	-	0.2
Siliqua sp.	-	0.3	-	-	-	-	-	0.2
Velutina prolongata	-	0.6	-	-	-	-	-	0.4
Velutina velutina	-	0.3	-	1.6	-	-	-	0.4
Yoldia myalis	-	0.6	-	-	-	0.7	-	0.6
Yoldia scissurata	-	0.3	-	-	-	-	-	0.2
Yoldia seminuda	-	-	-	-	-	0.7	-	0.2
Yoldia sp.	-	0.3	1.2	-	-	3.7	0.3	1.1
Unidentified pelecypoda	1.5	8.0	2.4	4.8	1.0	2.2	1.6	6.0
Gastropoda (snails)								
Amphissa columbiana	-	0.3	1.2	-	-	-	0.3	0.2
Buccinum sp.	-	0.3	-	-	-	-	-	0.2
Fusitriton oregonensis	0.7	0.3	-	3.2	-	-	0.3	0.6
Neptunea sp.	-	0.3	-	-	-	-	-	0.2
Beringius kennicottii	-	-	-	-	-	0.7	-	0.2
Polinices sp.	-	0.3	-	-	-	-	-	0.2
Trichotropis cancellata	-	0.3	-	-	-	0.7	-	0.4
Trophonopsis lasius	-	0.3	-	-	-	-	-	0.2
Turridae	-	0.3	-	-	-	-	-	0.2
Unidentified gastropoda	2.2 (5.1)	3.9 (17.9)	1.2 (4.8)	4.8 (12.9)	-	5.1 (15.3)	1.3 (3.8)	3.9 (16.6)
Cephalopoda (octopus)	2.2	1.2	2.4	1.6	2.0	-	2.2	0.9

245

BEST DOCUMENT AVAILABLE

TABLE I. Continued

FOOD ITEMS	1973		1974		1975		1973-75	
	M	NJ	M	NJ	M	M	M	NJ
	N=136	N=336	N=83	N=62	N=101	N=137	N=320	N=535
Arthropoda								
Crustacea								
Cirripedia (barnacles)	0.7	-	-	-	-	-	0.3	-
Euphausiacea (krill) and Mysidacea (mysids)	0.7	0.6	-	-	-	-	0.3	0.4
Isopoda (pill bugs)	-	0.6	-	-	-	1.5	-	0.7
Amphipoda (sand fleas)	1.5	55.7	-	40.3	2.0	44.8	0.6	51.1
Ampelisca macrocephala	0.7 (2.2)	2.7 (56.8)	-	-	-	0.7 (45.3)	0.3 (1.6)	1.9 (52.0)
Decapoda								
Pandalidae (shrimps)								
Pandalus borealis	-	0.6	2.4	4.8	-	0.7	0.6	1.1
Pandalus hypsinotus	-	0.3	-	1.6	-	-	-	0.4
Crangonidae (shrimps)	0.7	2.7	-	-	-	0.7	0.3	1.9
Unidentified shrimps	1.5 (2.2)	2.7 (6.0)	1.2 (2.4)	1.6 (8.1)	1.0	1.5 (1.5)	1.3 (1.9)	2.2 (5.0)
Paguridae (hermit crabs)								
Elassochirus gilli	-	0.9	-	-	-	-	-	0.6
Elassochirus tenuimanus	-	0.6	-	1.6	1.0	-	0.3	0.6
Pagurus ochotensis	-	-	-	-	2.0	1.5	0.6	0.4
Unidentified pagurids	1.5	7.4	2.4	3.2	1:0	6.6	1.6	6.7
Lithodidae (crabs)								
Acanthocephalothodes hispidus	-	0.3	-	-	-	-	-	0.2
Cryptolithodes sp.	-	0.3	-	-	-	-	-	0.2
Paralithodes camtschatica	-	2.1	-	-	-	1.5	-	1.7
Placetron wosnessenskii	1.5	6.4	1.2	-	1.0	0.7	1.2	1.3
Rhinolithodes wosnessenskii	-	0.3	-	-	-	-	-	0.2
Cancridae (crabs)								
Cancer oregonensis	0.7	6.3	-	4.8	2.0	1.5	0.9	4.9
Pinnotheridae (pea crabs)								
Pinnixa sp.	0.7	6.0	-	6.5	-	3.7	0.3	5.4
Majidae (spider or true crabs)								
Chionoecetes bairdi	33.8	14.0	36.1	6.5	48.5	27.9	39.1	16.7
Hyas lyratus	16.2	11.6	28.9	21.0	17.8	18.4	20.0	14.4
Oregonia gracilis	4.4	15.8	1.2	11.3	-	5.9	2.2	12.7
Unidentified crabs	1.3 (55.1)	3.3 (55.1)	- (63.9)	- (53.2)	- (64.4)	- (57.7)	0.6 (59.4)	2.1 (55.5)

TABLE 1. Continued

FOOD ITEMS	1973		1974		1975		1973-75	
	M N=136	NJ N=336	M N=83	NJ N=62	M N=101	M N=137	M N=320	NJ N=535
Brachiopoda (lamp shells)	-	0.6	-	-	-	-	-	0.6
Echinodermata								
Asteroidea (sea stars)	-	0.3	-	1.6	-	-	-	0.4
Echinoidea (sea urchins)	0.7	-	-	-	-	-	0.3	-
Holothuroidea (sea cucumbers)	-	3.9	-	1.6	-	2.9	-	3.4
Ophiuroidea (brittle stars)	-	4.8 (8.9)	-	- (3.2)	-	0.7 (3.6)	-	3.2 (6.9)
Chordata								
Urochordata (tunicates)	-	0.6	-	-	-	-	-	0.4
Vertebrata (fishes)								
Clupeidae (herring)								
Clupea harengus pallasi	-	0.6	-	-	-	-	-	-
Gadidae (cods)								
Theragra chalcogramma	0.7	-	1.2	-	4.0	-	1.9	-
Gadus macrocephalus	-	0.3	3.6	-	1.0	-	1.3	0.2
Zoarcidae (eelpouts)	-	0.3	-	-	-	-	-	0.2
Cottidae (sculpins)								
Hemilepidotus jordani	-	-	3.6	1.6	3.0	-	1.9	0.2
Myoxocephalus spp.	-	-	2.6	-	1.0	-	0.9	-
Unidentified cottid	9.6	0.9	15.7	3.2	1.0	0.7	8.4	1.1
Pleuronectidae (flatfishes)	2.9	0.3	2.4	1.6	1.0	-	1.6	0.4
Ammodytidae (sand lance)								
Ammodytes hexapterus	1.5	-	-	-	-	-	0.6	-
Unidentified fishes	16.2 (30.1)	6.3 (7.7)	13.3 (24.1)	1.6 (8.1)	13.9 (23.8)	2.9 (3.6)	14.7 (30.6)	4.9 (6.7)
Unidentified material	-	3.1	-	4.8	2.0	-	0.6	1.9
Empty	27.9	6.0	26.1	8.1	22.8	7.3	25.3	6.5

crabs in feeding fish was 55% (Table II). The mean number of snow crabs in feeding fish and fish containing snow crabs was 0.9 and 1.7 respectively. Snow crabs ingested included juveniles as well as adults (mean carapace width 63 mm [range 8 to 104 mm]); 23% of the snow crabs consumed in 1975 were ovigerous.

TABLE II

The Importance of the Snow Crab, *Chionoecetes bairdi*, in the Summer Diet of the Sculpins, *Myoxocephalus* spp.

Sampling Date

	1973 6/26-8/3	1974 6/28-7/31	1975 6/30-7/27	Total
No. of fishes examined	136	83	101	320
No. of fishes feeding	98	53	78	229
Percent of fishes feeding	72	64	77	72
No. of fishes containing crabs	46	30	49	125
Percent of fishes containing crabs	34(47)*	36(57)*	49(63)*	39(55)*
No. of crabs in stomach	107	41	61	209
Average crab occurrence in fishes containing crabs	2.3	1.4	1.2	1.7
Average crab width (mm)	54	60	74	63
Range crab width (mm)	8-104	31-95	12-99	8-104

* Percent in parenthesis is based on feeding fishes.

Five genera of fishes were identified; however, most were too far digested for generic or specific identification.

Hemilepidotus jordani

Based on all fish examined, crabs (55.5%), amphipods (52.0%), and pelecypods - gastropods (16.6%) were the dominant food groups consumed by *Hemilepidotus jordani* (Table I; Fig. 2). Three majid crabs were commonly found, *Chionoecetes bairdi* (16.7%), *Hyas lyratus* (14.4%), and *Oregonia gracilis* (12.7%). No significant difference ($\alpha = 0.05$) between the frequency occurrence of the three species of crabs was apparent when combining data for three years.

Amphipods were seldom identified; however, based on subjective estimates, *Anonyx nugax* is probably the principal species consumed. Amphipods which were occasionally preserved from stomach contents, as well as from the perforated bait containers in the crab pots, were later identified as mainly *A. nugax*. However, a few *Ampelisca macrocephala* were identified.

Of at least 27 species of pelecypods and gastropods consumed by *H. jordani*, most were found in 1973. No single species dominated.

GENERAL DISCUSSION

There are few references on the food of sculpins (see Hart, 1973 for general food comments on a variety of sculpin species). Mito (1974) examined the stomach contents of 64 *Myoxocephalus polyacanthocephalus* and 30 *Hemilepidotus jordani* from the southeastern Bering Sea. His samples were examined throughout the year. The dominant prey of *Myoxocephalus* was snow crabs (*Chionoecetes opilio*). Walleye pollock, miscellaneous fishes, cephalopods, and a majid crab (*Hyas coarctatus*) were next in decreasing order of importance. Polychaetes and benthic amphipods (*Anonyx* sp.) were rarely taken. Leading species in *Hemilepidotus*, in decreasing order of importance, were snow crabs, walleye pollock, polychaetes, anomuran crabs, *Hyas coarctatus*, pink shrimps, and amphipods (*Anonyx* sp.).

O'Connell (1953) reported on the life history of the cabezon (*Scorpaenichthys marmoratus*) in the summer in California, and found the food of adults to be dominated by crustaceans (78% by weight), specifically the crabs, *Cancer*, *Loxorhynchus*, and *Pugettia*. *Cancer* spp. mainly *C. magister*, becomes predominant earlier in the life of the cabezon than any of the other crab genera, and remains the most important prey throughout the life of the cabezon. Molluscs (10% by weight), specifically abalone, limpets, and chitons, were the next most important food of this sculpin. Fishes made up only 1.5% of the weight of the cabezon's summer diet.

The food of the staghorn sculpin (*Leptocottus armatus*) was examined from California waters during winter months by Jones (1962). He found the most common food among adult staghorn sculpins to be shrimps of the genera *Crago* (60% frequency of occurrence) and *Upogebia* (16%). The next most common food was the anchovy, *Engraulis mordax* (12.6%), although at least six other fish species were present.

Pacific cod (*Gadus macrocephalus*) taken simultaneous with sculpins from the Kodiak shelf frequently consumed snow crabs (*Chionoecetes bairdi*) (Jewett, 1978). The frequency of occurrence of snow crabs in all Pacific cod examined (36.7%) was similar to that of all *Myoxocephalus* that were examined (39.1%). The incidence of snow crabs in feeding Pacific cod was lower (39.2%) than the incidence in feeding *Myoxocephalus* (55%). However, the mean number of snow crabs in Pacific cod feeding on snow crabs was nearly double (3.3 crabs per individual) that of *Myoxocephalus* (1.7 crabs per individual). Although adult as well as juvenile snow crabs were taken by *Myoxocephalus*, no adult snow crabs (mean carapace width 14 mm [range 2 to 70 mm]) were found in Pacific cod.

Chionoecetes bairdi is important in Alaskan and world markets with landings for Kodiak increasing from 50.3 metric tons in 1967 to 9,409 metric tons in 1977 (ADF&G monthly shellfish report, unpubl.). Since snow crabs are a major item in the diet of *Myoxocephalus* spp. and Pacific cod, and to a limited extent in *Hemilepidotus jordani*, reduction of sculpin and cod stocks by a bait fishery may improve survival of young crabs, possibly enhancing recruitment of snow crabs to fishable stocks.

Because amphipods are attracted to bait, their frequency of occurrence (52%) in stomachs of *Hemilepidotus jordani* is presumably higher than normal and represents a prey of opportunity. The frequency of amphipods in pot-caught Pacific cod (22%) was higher than in trawl-caught cod (8.4%) (Jewett, 1978).

Trawl-caught sculpins were not available from the Kodiak shelf to compare with pot-caught sculpins. However, Jewett (1978) compared the food of Pacific cod caught by pots and trawls on the Kodiak shelf. Wilcoxon's paired-sample test indicated no significant difference ($\alpha = 0.05$) among food groups from cod caught by the two methods. Therefore, it is assumed that feeding data (excluding *Hemilepidotus jordani* feeding on amphipods) compiled from pot-caught sculpins on the Kodiak shelf reflect their normal, *in situ* diet. In summary, it is clear that *Myoxocephalus* spp. and *Hemilepidotus jordani*, like the cabezon, staghorn sculpin and the Pacific cod, are voracious benthic predators and, although their chief prey is Crustacea, they consume a wide variety of organisms.

ACKNOWLEDGMENTS

This study was partially supported under contract #03-5-022-56 between the University of Alaska (H. M. Feder) and NOAA, Department of Commerce through the Outer Continental Shelf Environmental Assessment Program to which funds were provided by the Bureau of Land Management, Department of the Interior. Thanks to George Mueller and Kenneth Vogt, of the Marine Sorting Center, University of Alaska, for their taxonomic assistance. Mollusc identifications were made by Rae Baxter, Alaska Department of Fish and Game.

REFERENCES

Feder, H. M. and S. C. Jewett. 1976. Distribution and abundance of some epibenthic invertebrates of the northeast Gulf of Alaska, with notes on the feeding biology of selected species. Inst. Mar. Sci., Univ. of Alaska. Rept. R76-8. 61 p.

Feder, H. M. and S. C. Jewett. 1977. The distribution, abundance, and diversity of the epifauna of two bays (Alitak and Ugak) of Kodiak Island, Alaska. Inst. Mar. Sci., Univ. of Alaska. Rept. R77-3. 74 p.

Feder, H. M. and S. C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea, and Kotzebue Sound. Inst. Mar. Sci., Univ. of Alaska. Rept. R78-1. 124 p.

Feder, H. M. and S. C. Jewett. In press. Survey of the epifaunal invertebrates of the southeastern Bering Sea with notes on the feeding biology of selected species of invertebrates and fishes. Inst. Mar. Sci., Univ. of Alaska. Rept R78-5.

Hart, J. L. 1973. Pacific Fishes of Canada. *Fish. Res. Bd. Can.* Bull. No. 180. 740 p.

Jewett, S. C. 1978. Summer food of the Pacific cod, *Gadus macrocephalus*, near Kodiak Island, Alaska. *Fish. Bull.* 76(3):700-706.

Jewett, S. C. and H. M. Feder. In press. Autumn food of adult starry flounders, *Platichthys stellatus*, from the northeastern Bering Sea and the southeastern Chukchi Sea. *J. Conseil, Conseil Perm. Intern. Exploration Mer.*

Jones, A. C. 1962. The biology of the euryhaline fish *Leptocotlus armatus* Girard. University of California Publications in Zoology. 67(4):321-365.

Lowry, L. F., K. J. Frost and J. J. Burns. In press. *In* B. R. Melteff (ed.). *Proceedings of the 29th Alaska Science Conference.* Alaska Fisheries: 200 years and 200 miles of change.

Mito, K. 1974. Food relationships in the demersal fish community in the Bering Sea--on the walleye pollock fishing grounds in October and November of 1972. Master's Thesis, Hokkaido University, Hakodate. 86 p.

O'Connell, C. P. 1953. The life history of the cabezon *Scorpaenichthys marmoratus* (Ayres). California Department of Fish and Game. *Fish. Bull.* No. 93. 76 p.

Paul, A. J., H. M. Feder and S. C. Jewett. In press. Food of the snow crab, *Chionoecetes bairdi* Rathbun, 1924 from Cook Inlet, Alaska (Decapoda, Majidae). Crustaceana.

Pennington, H. 1978. Alaska Bottomfish - 1978. *Alaska Seas and Coasts* 6(4):1-12.

Smith, R. L., A. C. Paulson, J. R. Rose. 1978. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. Final Report to NOAA. 70 p.

Reviewed by: H. M. Feder
R. L. Smith

BLANK PAGE

FINAL REPORT

THE INFAUNAL INVERTEBRATES OF THE SOUTHEASTERN BERING SEA

Dr. Howard M. Feder, Principal Investigator

with

Karl Haflinger
Max Hoberg
Judy McDonald

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

TABLE OF CONTENTS

LIST OF FIGURES 262

LIST OF TABLES. 268

SECTION 1 - A NUMERICAL ANALYSIS OF THE DISTRIBUTION OF THE BENTHIC INFAUNA OF THE SOUTHEASTERN BERING SEA SHELF. 272

- I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT 274
- II. INTRODUCTION. 276
  - General Nature and Scope of Study 276
  - Specific Objectives 278
  - Relevance to Problems of Petroleum Development. . . 279
- III. CURRENT STATE OF KNOWLEDGE. 281
- IV. STUDY AREA. 282
- V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION. 284
- VI. RESULTS 287
- VII. DISCUSSION. 289
  - Performance of the 0.1 m^2 van Veen Grab 289
  - Number of Grab Samples Per Station. 290
  - Station Coverage. 290
  - Species Composition of the Stations 291
  - Diversity Indices 291
  - Biologically Important Taxa 292
  - Feeding Methods 292
  - Clam Studies in the Bering Sea. 294
- VIII. CONCLUSIONS 295
- IX. NEEDS FOR FURTHER STUDY 297

APPENDIX 1.A - SUMMARY OF DATA COLLECTED BY VAN VEEN GRAB AT 60 STATIONS IN THE SOUTHEASTERN BERING SEA 300

APPENDIX 1.B - A NUMERICAL ANALYSIS OF THE DISTRIBUTION OF THE BENTHIC INFAUNA OF THE SOUTHEASTERN BERING SEA SHELF. M.S. THESIS BY KARL E. HAFLINGER 303

SECTION 2 - THE DISTRIBUTION OF BIVALVE MOLLUSCS IN THE SOUTHEASTERN BERING SEA WITH EMPHASIS ON EIGHT SPECIES IN RELATION TO SEDIMENT. 405

- I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OIL AND GAS DEVELOPMENT 407
- II. INTRODUCTION. 408
  - General Nature and Scope of Study 409
  - Relevance to Problems of Petroleum Development. . . 409
- III. CURRENT STATE OF KNOWLEDGE. 409

TABLE OF CONTENTS

Continued

IV. STUDY AREA. 409
V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION. 419
VI. RESULTS 424
VII. DISCUSSION. 452
VIII. CONCLUSIONS 456

APPENDIX 2.A - SOUTHEASTERN BERING SEA GRAB DATA 1975. THE DENSITY (COUNTS/M^2) OF ALL CLAMS TAKEN BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA. 459
APPENDIX 2.B - SOUTHEASTERN BERING SEA CLAMS COLLECTED BY PIPE DREDGE ON THE NOAA VESSEL *MILLER FREEMAN*, MAY 1976. 464
APPENDIX 2.C - SOUTHEASTERN BERING SEA GRAB DATA 1975. THE BIOMASS (FORMALIN WET WEIGHT, GRAMS/M^2) OF ALL CLAMS TAKEN BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA 467
APPENDIX 2.D - THREE PARAMETERS AT WHICH THE MAJOR CONCENTRATIONS OF EIGHT SPECIES OF CLAMS, TAKEN BY VAN VEEN GRAB, OCCUR IN THE SOUTHEASTERN BERING SEA. 479

SECTION 3 - THE DISTRIBUTION OF COMMON INFAUNA, OTHER THAN CLAMS, AND SESSILE AND SLOW-MOVING EPIFAUNA IN THE SOUTHEASTERN BERING SEA. 474

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OIL AND GAS DEVELOPMENT 475
II. INTRODUCTION. 476

General Nature and Scope of Study 476
Relevance to Problems of Petroleum Development. . . 477

III. CURRENT STATE OF KNOWLEDGE. 477
IV. STUDY AREA. 477
V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION. 478
VI. RESULTS 478

Density and Biomass 499

VII. DISCUSSION. 502
VIII. CONCLUSIONS 504

APPENDIX 3.A - SOUTHEASTERN BERING SEA GRAB DATA 1975. THE DENSITY (COUNTS/M^2) OF DOMINANT INFAUNAL SPECIES COLLECTED BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA 507

TABLE OF CONTENTS

Continued

APPENDIX 3.B - SOUTHEASTERN BERING SEA PIPE DREDGE DATA 1975. 510

APPENDIX 3.C - SOUTHEASTERN BERING SEA GRAB DATA 1975. THE BIOMASS (FORMALIN WET WEIGHT, GRAMS/M^2) OF DOMINANT INFAUNAL SPECIES COLLECTED BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA 513

APPENDIX 3.D - THREE PARAMETERS AT WHICH THE MAJOR CONCENTRATIONS OF ELEVEN SPECIES OF INVERTEBRATES, TAKEN BY VAN VEEN GRAB, OCCUR IN THE SOUTHEASTERN BERING SEA. 516

SECTION 4 - DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES INCIDENTLY COLLECTED BY CLAM DREDGE BY THE F/V *SMARAGD*. . . . 518

- I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT 519
- II. INTRODUCTION. 519
- III. CURRENT STATE OF KNOWLEDGE. 520
- IV. STUDY AREA. 520
- V. METHODS 528
- VI. RESULTS 529
- VII. DISCUSSION. 552
- VIII. CONCLUSION. 562

APPENDIX 4.A - DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE 563

APPENDIX 4.B - GROWTH AND SIZE OF THE PINKNECK CLAM, *SPISULA POLYNYMA* IN THE EASTERN BERING SEA 570

SECTION 5 - BIOLOGY OF SIX SELECTED SPECIES OF SUBTIDAL CLAMS FROM THE SOUTHEASTERN BERING SEA. 592

- I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT 594
- II. INTRODUCTION. 595
  - General Nature and Scope of Study 595
  - Relevance to Problems of Petroleum Development. . . 595
- III. CURRENT STATE OF KNOWLEDGE. 595
- IV. STUDY AREA. 596
- V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION. 596
- VI. RESULTS - DISCUSSION 600
  - Biology of Clams - Individual Species 600

TABLE OF CONTENTS

Continued

VII. GENERAL DISCUSSION. 657
A Comparison of Species . . . .
General 657
VIII. GENERAL CONCLUSIONS 659
REFERENCES. 661
. . . . 662

LIST OF FIGURES

Figure 2.1. Three regions of the eastern Bering Sea discussed in the present report (modified from Sharma, 1972) 411

Figure 2.2. Distribution of sediment size (mean phi) in the southeastern Bering Sea 412

Figure 2.3. Distribution of gravel in the southeastern Bering Sea 413

Figure 2.4. Distribution of sand fraction in the southeastern Bering Sea 414

Figure 2.5. Distribution of mud fraction in the southeastern Bering Sea 415

Figure 2.6. Sediment sorting in the southeastern Bering Sea. 416

Figure 2.7. Infaunal stations occupied in the eastern Bering Sea, May 1976 418

Figure 2.8. Distribution of *Nucula tenuis* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 425

Figure 2.9. Quantitative distribution of *Nucula tenuis* taken by van Veen grab 426

Figure 2.10. Distribution of *Nucula tenuis* collected by pipe dredge and associated phi values. 427

Figure 2.11. Distribution of *Nuculana fossa* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 431

Figure 2.12. Quantitative distribution of *Nuculana fossa* taken by van Veen grab 432

Figure 2.13. Distribution of *Nuculana fossa* collected by pipe dredge, and phi values associated with the clam distribution. 433

Figure 2.14. Distribution of *Cyclocardia crebricostata* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 434

Figure 2.15. Quantitative distribution of *Cyclocardia crebricostata* taken by van Veen grab 435

Figure 2.16. Distribution of *Cyclocardia crebricostata* collected by pipe dredge, and phi values associated with the clam distribution. 436

Figure 2.17. Distribution of *Macoma calcarea* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 438

LIST OF FIGURES

Continued

Figure 2.18. Quantitative distribution of *Macoma calcarea* taken by van Veen grab 439

Figure 2.19. Distribution of *Macoma calcarea* collected by pipe dredge, and phi values associated with the clam distribution. 440

Figure 2.20. Distribution of *Clinocardium ciliatum* based on collection taken with a grab, pipe dredge, clam dredge and otter trawl. 441

Figure 2.21. Quantitative distribution of *Clinocardium ciliatum* taken by van Veen grab. 442

Figure 2.22. Distribution of *Clinocardium ciliatum* collected by pipe dredge, and phi values associated with the clam distribution. 444

Figure 2.23. Distribution of *Yoldia amygdalea* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 445

Figure 2.24. Quantitative distribution of *Yoldia amygdalea* taken by van Veen grab 446

Figure 2.25. Distribution of *Yoldia amygdalea* collected by pipe dredge, and phi values associated with the clam distribution. 447

Figure 2.26. Distribution of *Tellina lutea* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 448

Figure 2.27. Quantitative distribution of *Tellina lutea* taken by van Veen grab 449

Figure 2.28. Distribution of *Tellina lutea* collected by pipe dredge, and phi values associated with the clam distribution. 451

Figure 2.29. Distribution of *Spisula polynyma* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 452

Figure 3.1. Distribution of *Solariella obscura* and *Solariella varicosa* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 485

Figure 3.2. Distribution of *Margarites olivaceus* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 489

Figure 3.3. Distribution of *Polinices pallida* and *Natica clausa* based on collection taken with a grab, pipe dredge, clam dredge and otter trawl 491

LIST OF FIGURES

Continued

Figure 3.4. Distribution of *Cylichna alba* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 492

Figure 3.5. Distribution of *Echinarachnius parma* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 494

Figure 3.6. Distribution of *Diamphiodia craterodmeta* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 496

Figure 3.7. Distribution of *Ophiura sarsi* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl 497

Figure 3.8. Distribution of *Cucumaria calcigera* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 498

Figure 3.9. Distribution of *Boltenia ovifera* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl. 500

Figure 4.1. National Marine Fisheries Service Bering Sea trawl survey shows locations (shaded) of 400 square mile areas (blocks) where pinkneck clams (*Spisula polynyma*) were obtained in otter trawl surveys. 527

Figure 4.2. The distribution of the polychaete, *Nephtys caeca*, taken by hydraulic dredge 544

Figure 4.3. The distribution of the polychaete, *Nicomache* sp., taken by hydraulic dredge. 545

Figure 4.4. The distribution of the polychaete, *Sabella media*, taken by hydraulic dredge. 546

Figure 4.5. The distribution of the clam, *Astarte rollandi*, taken by hydraulic dredge. 547

Figure 4.6. The distribution of the cockle, *Cyclocardia crebricostata*, taken by hydraulic dredge 548

Figure 4.7. The distribution of the clam, *Serripes groenlandicus*, taken by hydraulic dredge 549

Figure 4.8. The distribution of the clam, *Serripes laperousii*, taken by hydraulic dredge. 550

Figure 4.9. The distribution of the clam, *Spisula polynyma*, taken by hydraulic dredge. 551

Figure 4.10. The distribution of the clam, *Macoma calcarea*, taken by hydraulic dredge. 552

LIST OF FIGURES

Continued

Figure 4.11. The distribution of the clam, *Macoma middendorffi*, taken by hydraulic dredge 554

Figure 4.12. The distribution of the clam, *Tellina lutea*, taken by hydraulic dredge 555

Figure 4.13. The distribution of the snail, *Neptunea heros*, taken by hydraulic dredge 556

Figure 4.14. The distribution of the snail, *Neptunea ventricosa*, taken by hydraulic dredge 557

Figure 4.15. The distribution of the sea star, *Asterias amurensis*, taken by hydraulic dredge. 558

Figure 4.16. The distribution of the sand dollar, *Echinarachnius parma*, taken by hydraulic dredge. 559

Figure 4.17. The distribution of the sea squirt or tunicate, *Boltenia ovifera*, taken by hydraulic dredge 560

Figure 4.18. The distribution of the sea squirt or tunicate, *Styela rustica macrenteron*, taken by hydraulic dredge. 561

Figure 5.1. Location of stations where clam samples were collected 597

Figure 5.2. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 12 in the southeastern Bering Sea 601

Figure 5.3. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 18 in the southeastern Bering Sea 602

Figure 5.4. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 19 in the southeastern Bering Sea 603

Figure 5.5. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 30 in the southeastern Bering Sea 604

Figure 5.6. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 70 in the southeastern Bering Sea 605

Figure 5.7. A comparison of shell length (mm) and age between six stations for *Nucula tenuis* in the southeastern Bering Sea 609

Figure 5.8. The growth history of *Nucula tenuis* from Station 12 in the southeastern Bering Sea 610

Figure 5.9. The growth history of *Nucula tenuis* from Station 18 in the southeastern Bering Sea 610

LIST OF FIGURES

Continued

Figure 5.10. The growth history of *Nucula tenuis* from Station 19 in the southeastern Bering Sea 611

Figure 5.11. The growth history of *Nucula tenuis* from Station 30 in the southeastern Bering Sea 611

Figure 5.12. The growth history of *Nucula tenuis* from Station 70 in the southeastern Bering Sea 612

Figure 5.13. Graph of abundance *vs* age for all *Nucula tenuis* collected. 614

Figure 5.14. The relationship between shell length (mm) and age of *Nuculana fossa* at Station 28 in in the southeastern Bering Sea. 616

Figure 5.15. The relationship between shell length (mm) and age of *Nuculana fossa* at Station 64 in the southeastern Bering Sea 617

Figure 5.16. The relationship between shell length (mm) and age of *Nuculana fossa* at Station 70 in the southeastern Bering Sea 618

Figure 5.17. A comparison of shell length (mm) and age between four station for *Nuculana fossa* in the southeastern Bering Sea 624

Figure 5.18. The growth history of *Nuculana fossa* from Station 28 in the southeastern Bering Sea 625

Figure 5.19. The growth history of *Nuculana fossa* from Station 64 in the southeastern Bering Sea 625

Figure 5.20. The growth history of *Nuculana fossa* from Station 70 in the southeastern Bering Sea 626

Figure 5.21. Graph of abundance *vs* age for all *Nuculana fossa* collected 627

Figure 5.22. The relationship between shell length (mm) and age of *Yoldia amygdalea* at Station A70 in the southeastern Bering Sea. 630

Figure 5.23. The growth history of *Yoldia amygdalea* from Station A70 in the southeastern Bering Sea. 633

Figure 5.24. A comparison of shell length (mm) and age between two stations for *Yoldia amygdalea* in the southeastern Bering Sea 634

Figure 5.25. The relationship between shell length (mm) and age of *Spisula polynyma* at Station 9 in the southeastern Bering Sea 635

LIST OF FIGURES

Continued

Figure 5.26. The relationship between shell length (mm) and age of *Spisula polynyma* at Station 55 in the southeastern Bering Sea 635

Figure 5.27. A comparison of shell length (mm) and age between two stations for *Spisula polynyma* in the southeastern Bering Sea 639

Figure 5.28. The relationship between shell length (mm) and age of *Tellina lutea* at Station 5 in the southeastern Bering Sea 640

Figure 5.29. The growth history of *Tellina lutea* from Station 5 in the southeastern Bering Sea. 644

Figure 5.30. The relationship between shell length (mm) and age of *Macoma calcarea* at Station 28 in the southeastern Bering Sea 647

Figure 5.31. The relationship between shell length (mm) and age of *Macoma calcarea* at Station 64 in the southeastern Bering Sea 648

Figure 5.32. The relationship between shell length (mm) and age of *Macoma calcarea* at Station 70 in the southeastern Bering Sea 649

Figure 5.33. The relationship between shell length (mm) and age of *Macoma calcarea* at Station A70 in the southeastern Bering Sea. 650

Figure 5.34. The growth history of *Macoma calcarea* from Station 28 in the southeastern Bering Sea 653

Figure 5.35. The growth history of *Macoma calcarea* from Station 64 in the southeastern Bering Sea 654

Figure 5.36. The growth history of *Macoma calcarea* from Station 70 in the southeastern Bering Sea 655

Figure 5.37. The growth history of *Macoma calcarea* from Station A70 in the southeastern Bering Sea. 655

Figure 5.38. A comparison of shell length (mm) and age between four stations for *Macoma calcarea* in the southeastern Bering Sea. 656

Figure 5.39. Abundance *vs* age for all *Macoma calcarea* aged in the collection. 658

LIST OF TABLES

Table 2.I. Sediment data from R/V *Discoverer* van Veen grab data 1975 420

Table 2.II. A comparison of five methods used for description of sediments 423

Table 2.III. Percentage of pelecypods collected at each phi value based on grab samples. 428

Table 2.IV. Percentage of pelecypod species by sediment sorting values based on southeastern Bering Sea grab data 1975 430

Table 2.V. Percentage of pelecypod species by depth, based on southeastern Bering Sea grab data 1975 439

Table 2.VI. Total number of clams/m^2 by station on the southeastern Bering Sea shelf. 454

Table 2.VII. Biomass (g/m^2) by station on the southeastern Bering Sea shelf 454

Table 3.I. Species collected by pipe dredge at 44 stations in the southeast Bering Sea. 479

Table 3.II. The invertebrate phyla and the number and percentage of each phylum collected by pipe dredge and van Veen grab in the Bering Sea 484

Table 3.III. Percent of selected benthic species collected at each phi value using a van Veen grab in the southeast Bering Sea 487

Table 3.IV. Percent of selected benthic species by sediment sorting values based on southeastern Bering Sea grab data 1975 487

Table 3.V. Percent of selected benthic species by depth based on southeastern Bering Sea data 1975 488

Table 3.VI. Total number of common invertebrates/m^2 by station on the southeastern Bering Sea shelf. 501

Table 3.VII. G/m^2 by station on the southeastern Bering Sea shelf. 503

Table 4.I. Stations occupied in the Bering Sea on the *Spisula polynyma* survey by the F/V *Smaragd* and the number of clams collected by station 521

Table 4.II. A list of species taken by hydraulic dredge by the F/V *Smaragd* in the southeastern Bering Sea 530

Table 4.III. Percentage composition by weight - all phyla 532

Table 4.IV. Composition of all phyla by family 533

LIST OF TABLES

Continued

Table 4.V. Composition of all phyla by species. 535

Table 4.VI. Occurrences of each species. 540

Table 5.I. The number of specimens aged from pipe dredge collection in the Bering Sea, May 1976 599

Table 5.II. The age composition and shell lengths of *Nucula tenuis* from six stations (12, 18, 19, 30, 38, and 70) in the eastern Bering Sea. 601

Table 5.III. The age composition and shell lengths of *Nucula tenuis* from Station 12 in the eastern Bering Sea . . . 606

Table 5.IV. The age composition and shell lengths of *Nucula tenuis* from Station 18 in the eastern Bering Sea . . . 606

Table 5.V. The age composition and shell lengths of *Nucula tenuis* from Station 19 in the eastern Bering Sea . . . 607

Table 5.VI. The age composition and shell lengths of *Nucula tenuis* from Station 30 in the eastern Bering Sea . . . 607

Table 5.VII. The age composition and shell lengths of *Nucula tenuis* from Station 38 in the eastern Bering Sea . . . 608

Table 5.VIII. The age composition and shell lengths of *Nucula tenuis* from Station 70 in the eastern Bering Sea . . . 608

Table 5.IX. The distribution of *Nucula tenuis* at each age and the relationship between age and natural mortality . . 614

Table 5.X. A comparison of mean shell lengths and age for *Nucula tenuis* from three studies 615

Table 5.XI. The age composition and shell lengths of *Nuculana fossa* from nine stations (17, 18, 28, 30, 64, A69, 70, A70, and B86) in the eastern Bering Sea . . . 615

Table 5.XII. The age composition and shell lengths of *Nuculana fossa* from Station 17 in the eastern Bering Sea. . . . 619

Table 5.XIII. The age composition and shell lengths of *Nuculana fossa* from Station 18 in the eastern Bering Sea. . . . 619

Table 5.XIV. The age composition and shell lengths of *Nuculana fossa* from Station 28 in the eastern Bering Sea. . . . 620

Table 5.XV. The age composition and shell lengths of *Nuculana fossa* from Station 30 in the eastern Bering Sea. . . . 620

Table 5.XVI. The age composition and shell lengths of *Nuculana fossa* from Station 64 in the eastern Bering Sea. . . . 621

Table 5.XVII. The age composition and shell lengths of *Nuculana fossa* from Station 1769 in the eastern Bering Sea. . . 621

LIST OF TABLES
Continued

Table 5.XVIII. The age composition and shell lengths of *Nuculana fossa* from Station 70 in the eastern Bering Sea . . . 622

Table 5.XIX. The age composition and shell lengths of *Nuculana fossa* from Station A70 in the eastern Bering Sea. . . 622

Table 5.XX. The age composition and shell lengths of *Nuculana fossa* from Station B86 in the eastern Bering Sea. . . 622

Table 5.XXI. The distribution of *Nuculana fossa* at each age and the relationship between age and natural mortality 626

Table 5.XXII. A comparison of mean shell lengths and age for *Nuculana fossa* from three studies 628

Table 5.XXIII. The age composition and shell lengths of *Yoldia amygdalea* from three stations (38, 70, and A70) in the eastern Bering Sea 628

Table 5.XXIV. The age composition and shell lengths of *Yoldia amygdalea* from Station 38 in the eastern Bering Sea 631

Table 5.XXV. The age composition and shell lengths of *Yoldia amygdalea* from Station 70 in the eastern Bering Sea 631

Table 5.XXVI. The age composition and shell lengths of *Yoldia amygdalea* from Station A70 in the eastern Bering Sea 632

Table 5.XXVII. The age composition and shell lengths of *Spisula polynyma* from two stations (9 and 55) in the eastern Bering Sea. 634

Table 5.XXVIII. The age composition and shell lengths of *Spisula polynyma* from Station 9 in the eastern Bering Sea 638

Table 5.XXIX. The age composition and shell lengths of *Spisula polynyma* from Station 55 in the eastern Bering Sea 638

Table 5.XXX. The age composition and shell lengths of *Tellina lutea* from six stations (4, 5, 6, 22, 23, and 25) in the eastern Bering Sea 639

Table 5.XXXI. The age composition and shell lengths of *Tellina lutea* from Station 4 in the eastern Bering Sea. . . . 641

Table 5.XXXII. The age composition and shell lengths of *Tellina lutea* from Station 5 in the eastern Bering Sea. . . . 641

LIST OF TABLES

Continued

Table 5.XXXIII. The age composition and shell lengths of *Tellina lutea* from Station 6 in the eastern Bering Sea . . . 642

Table 5.XXXIV. The age composition and shell lengths of *Tellina lutea* from Station 22 in the eastern Bering Sea. . . 642

Table 5.XXXV. The age composition and shell lengths of *Tellina lutea* from Station 23 in the eastern Bering Sea. . . 642

Table 5.XXXVI. The age composition and shell lengths of *Tellina lutea* from Station 25 in the eastern Bering Sea. . . 643

Table 5.XXXVII. The age composition and shell lengths of *Macoma calcarea* from four stations (28, 64, 70, and A70) in the eastern Bering Sea. 646

Table 5.XXXVIII. The age composition and shell lengths of *Macoma calcarea* from Station 28 in the eastern Bering Sea. 651

Table 5.XXXIX. The age composition and shell lengths of *Macoma calcarea* from Station 64 in the eastern Bering Sea. 651

Table 5.XL. The age composition and shell lengths of *Macoma calcarea* from Station 70 in the eastern Bering Sea. 652

Table 5.XLI. The age composition and shell lengths of *Macoma calcarea* from Station A70 in the eastern Bering Sea. 652

Table 5.XLII. The distribution of *Macoma calcarea* at each age and the relationship between age and natural mortality. 658

Table 5.XLIII. A comparison of mean shell lengths and age of *Macoma calcarea* from four studies. 659

Table 5.XLIV. Age and mean shell lengths of six species of bivalves from several southeastern Bering Sea stations 659

SECTION 1

A NUMERICAL ANALYSIS OF THE DISTRIBUTION OF THE BENTHIC INFAUNA OF THE SOUTHEASTERN BERING SEA SHELF

ACKNOWLEDGEMENTS

We would like to thank the following for assistance onboard ship: Dr. James Morrow, E. Dieter, Dave Hallbert, Andy Grossman, Gretchen Keiser, Bill Kopplin and Robert Roark. Thanks go to the officers and the crew of the R/V *Discoverer* and the NOAA Ship *Miller Freeman* for their support in the sampling program. The assistance of the Marine Sorting Center, University of Alaska is acknowledged. The assistance of Dave Nebert and Rosemary Hobson, Institute of Marine Science, University of Alaska, in the initial phases of coding and preparation of species listings for computer analysis is appreciated. Cydney Hansen, Data Processing, University of Alaska, assisted with programming problems.

We thank Ana Lea Vincent (Publications, Institute of Marine Science, University of Alaska) for drafting of all figures in this report, and the staff of the Institute of Marine Science Publications Department for assistance.

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study were (1) a quantitative inventory of dominant benthic species within and adjacent to identified oil-lease sites in the southeastern Bering Sea, (2) to distinguish species assemblages on the basis of distribution and abundance of infaunal species on the southeastern Bering Sea shelf, and (3) a preliminary comparison of dominant species with selected physical and geological features.

A total of 77 widely dispersed permanent stations for quantitative grab sampling were established in the Bering Sea and 62 of these stations were analyzed for this report.

The general patchiness of fauna observed at most stations in the first year of study suggested that at least five replicates be taken per station. At least this number of replicates was typically taken at each station.

Approximately six-hundred and sixty-five different infaunal and slow-moving infaunal organisms were determined. Since fragments of organisms were commonly encountered, many identifications could only be made to taxonomic levels higher than that of species. For a limited number of species, it was not possible to make specific determinations based on available taxonomy for particular groups. However, four hundred and sixty-four distinct species were identified. It is probable that all species with numerical and biomass importance have been collected in the area of investigation and that only rare species will be added in future sampling.

No consistent seasonal information is available for the infaunal benthos of the southeastern Bering Sea from this Outer Continental Shelf Environmental Assessment Program (OCSEAP) project, although limited seasonal data are available in the literature.

Basic information on diversity for grab stations is available for all stations on the Bering Sea grid. Caution is indicated in the interpretation of these values until data are available over a longer time base.

Criteria established for Biologically Important Taxa (BIT) have delineated 89 species in the southeastern Bering Sea.

Multivariate techniques were employed to examine groupings of stations and species on the southeastern Bering Sea shelf. In order to use multivariate techniques, a significant reduction in the number of species to be considered was necessary. Only those species occurring at five or more stations were included in the numerical analysis; one hundred and eighty (180) such species were found.

The combined use of the multivariate techniques of cluster analysis, principal components, and principal coordinates analysis led to generalizations concerning station groups and species assemblages in the study area.

1. Five major station groups were found to encompass 47 of the 62 stations under study. Three main station groups account for 39 of these stations. These three groups occupy adjacent bands whose long axes roughly parallel the bathymetry, defining contiguous areas of increasing depth. Two smaller groups (4 stations each) are found in the vicinity of the head of Bristol Bay and around Nunivak Island.
2. Fifty-six species assemblages have been delineated. The distribution of thirteen of these show strong correlations with the major station groups. Two broad classes of the species groups are obvious: (a) those with distributions generally confined to a single station group, and (b) those considered ubiquitous but showing marked changes in numbers at the different station groups.

Several ecological differences between the main station groups are evident.

1. In general, an inshore/offshore polarity exists, with high numbers of individuals being found in the coarse sand bottoms of the inshore areas and progressively lower abundances in the finer sediments of the offshore areas (MSG and OSG).
2. An increase in the ratio of suspension-feeding species to other trophic types was seen in the mid-shelf area. The differences in the ratio between groups is thought to be the result of a difference in food supply and differences in the effect of storm-wave-induced turbulence on the shallow-dwelling suspension feeding community.

3. A near absence of suspension-feeding individuals in the coarse sand and gravel areas at the head of Bristol Bay (IG2).

4. A low diversity in the mid-shelf area (MSG) when compared to both the inner and outer shelf groups (IG1 and OSG). In the former case (IG1), high diversity stems from the large number of individuals present, while in the latter case (OSG) it results from high species richness (i.e., high numbers of species found at each station).

Initial assessment of all data suggests that: (1) sufficient station uniqueness exists to permit development of monitoring programs based on species composition at selected stations utilizing both grab and trawl sampling techniques, and (2) adequate numbers of biologically well-known, unique, abundant, and/or large species are available to permit nomination of likely monitoring candidates for the areas if industrial activity is initiated.

II. INTRODUCTION

General Nature and Scope of Study

The operations connected with oil exploration, production, and transportation in the Bering Sea present a wide spectrum of potential dangers to the marine environment (see Olson and Burgess, 1967, for general discussion of marine pollution problems). Adverse effects on the marine environment of these areas cannot be quantitatively assessed, or even predicted, unless background data are recorded prior to industrial development.

Insufficient long-term information about an environment, and the basic biology and recruitment of species in that environment, can lead to erroneous interpretations of changes in types and density of species that might occur if the area becomes altered (see Nelson-Smith, 1973; Pearson, 1971, 1972, 1975; Rosenberg, 1973; Pearson and Rosenberg, 1978, for general discussions on benthic biological investigations in industrialized marine areas). Populations of marine species fluctuate over a time span of a few to 30 years (Lewis, 1970, and personal communication). Such fluctuations are typically unexplainable because of absence of long-term data on physical and chemical environmental parameters in association with biological information on the species involved (Lewis, 1970, and personal communication).

Benthic organisms (primarily the infauna but also sessile and slow-moving epifauna) are particularly useful as indicator species for a disturbed area because they tend to remain in place, typically react to long-range environmental changes, and by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects, and are believed to reflect the biological health of a marine area (see Pearson, 1971, 1972, 1975; Rosenberg, 1973; Pearson and Rosenberg, 1978, for discussion on long-term usage of benthic organisms for monitoring pollution).

The presence of large numbers of benthic epifaunal species of actual or potential commercial importance (crabs, shrimps, snails, finfishes) in the Bering Sea further dictates the necessity of understanding benthic communities since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963; Feder *et al.*, 1978a, 1979; Feder and Jewett, in press, for discussions of the interaction of commercial species and the benthos; also see appropriate discussions in Sections 2, 3, 4, 5 of this report). Any drastic changes in density of the food benthos could affect the health and numbers of these commercially important species.

Experience in pollution-prone areas of England (Smith, 1968), Scotland (Pearson, 1972, 1975; Pearson and Rosenberg, 1978), and California (Straughan, 1971) suggests that at the completion of an initial exploratory study, selected stations should be examined regularly on a long-term basis to determine any changes in species content, diversity, abundance and biomass. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration. Intensive investigations of the benthos of the Bering Sea are also essential to an understanding of the trophic interactions involved in these areas and the potential changes that could take place once oil-related activities are initiated. The benthic macrofauna of the Bering Sea is relatively well known taxonomically, and some data on distribution, abundance, general biology, and feeding mechanisms are reported in the literature (Feder *et al.*, 1976a; Feder and Mueller, 1977; Feder *et al.*, 1978b). The relationship of specific infaunal feeding types to certain substrate conditions has limited documentation as well. However, detailed information on the temporal and spatial variability of the benthic fauna is sparse, and the relationship of benthic species to the overlying seasonal ice cover is not known. Some of the macrofaunal benthic species may be impacted by oil-related activities. An understanding of these benthic species and their interactions with each other and various aspects of the abiotic features of their environment are essential to the development of environmental predictive capabilities for the Bering Sea.

The benthic biological program in the southeastern Bering Sea during its first year emphasized development of a qualitative and quantitative inventory of species as part of the overall examination of the biological, physical and chemical components of those portion of the shelf slated for oil exploration and drilling activity. In addition, development of computer programs for use with data collected in the northeast Gulf of Alaska, designed to quantitatively assess assemblages of benthic species on the shelf there, was applicable to the southeastern Bering Sea (Feder and Matheke, 1979). The resultant computer analysis expands the understanding of distribution patterns of species in the latter area.

The study program was designed to survey and define variability of the benthic fauna on the southeastern Bering Sea shelf in regions of offshore oil and gas concentrations. During the first phases of research, emphasis was placed on the collection of data on the faunal composition and abundance of shelf infauna to form baselines to which potential future changes could be compared. Future development of long-term studies on life histories and trophic interactions should clarify which components of the various species groups are vulnerable to environmental damage, and should help to determine the rates at which damaged environments can recover.

Specific Objectives

1. A quantitative inventory of dominant benthic species within identified oil-lease sites.

2. A description of spatial distribution patterns of selected species in the designated study area.

3. A preliminary comparison of the distribution of dominant species with physical, chemical, and geological features with emphasis on the latter parameter.

Relevance to Problems of Petroleum Development

The effects of oil pollution on subtidal benthic organisms have been seriously neglected, although a few studies, conducted after serious oil spills, have been published (see Boesch *et al.*, 1974, for review of these papers). Thus, lack of a broad data base elsewhere makes it difficult at present to predict the effects of oil-related activity on the subtidal benthos of the Bering Sea. However, research activities in Alaska OCSEAP areas should ultimately enable us to point with some confidence to certain species or regions that might bear closer scrutiny once industrial activity is initiated. It must be emphasized that a considerable time frame is needed to comprehend long-term fluctuations in density of marine benthic species; thus, it cannot be expected that short-term research programs will result in predictive capabilities. Assessment of the environment must be conducted on a continuing basis.

As indicated previously, infaunal benthic organisms tend to remain in place and consequently have been useful as an indicator species for disturbed areas. Thus, close examination of stations with substantial complements of infaunal species is warranted (see NODC infaunal data submitted by H. Feder on file for the southeast Bering Sea for examples of such stations). Changes in the environment at these and other stations with relatively large number of species might be reflected in a decrease in species diversity with increased dominance of a few (see Nelson-Smith, 1973, for further discussion of oil-related changes in diversity). Likewise, stations with substantial numbers of epifaunal species should be assessed on a continuing basis (see Feder *et al.*, 1978c; Feder and Jewett, in press, for references to relevant stations). The potential effects of loss of specific species to the overall trophic structure in the Bering Sea cannot be fully assessed at this time, but the problem can probably be better addressed utilizing preliminary information on benthic food studies now available in Feder *et al.* (1978c); Feder and Jewett (in press); and Smith *et al.* (1978).

Data indicating the effect of oil on subtidal benthic invertebrates are fragmentary; however, echinoderms are "notoriously sensitive to any reduction in water quality" (Nelson-Smith, 1973). Echinoderms (ophiuroids, asteroids, and holothuroids) are conspicuous members of the benthos of the Bering Sea (Feder *et al.*, 1978c; Feder and Jewett, in press; and Feder Bering Sea NODC submitted data), and could be affected by oil activities there. Asteroids (sea stars) and ophiuroids (brittle stars) are often important components of the diet of large crabs (for example, the king crab feeds on sea stars and brittle stars: unpub. data, Guy Powell, Alaska Dept. of Fish and Game; Feder *et al.*, 1979) and demersal fishes (Feder, unpub. data; Jewett and Feder, in press). The tanner or snow crabs (*Chionoecetes bairdi* and *C. opilio*) are conspicuous members of the shallow shelf of the Bering Sea, and support commercial fisheries of considerable importance. Laboratory experiments with *C. bairdi* have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil; obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this species (Karinen and Rice, 1974). Little other direct data based on laboratory experiments are available for subtidal benthic species (Nelson-Smith, 1973).

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974, for review). A diesel-fuel oil spill resulted in oil becoming adsorbed on sediment particles with the resultant mortality of many deposit feeders living on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. The most common members of the infauna of the Bering Sea infauna are deposit feeders; thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime with subsequent alteration of species composition.

As suggested above, upon completion of initial baseline studies in pollution prone areas, selected stations should be examined regularly on a long-term basis. Cluster analysis technques discussed below, supplemented by principal coordinate and/or principal components analysis, should provide technique for selection of stations to be used for continuous monitoring of infauna. In addition, these techniques should provide an insight into normal ecosystem variation (Clifford and Stephenson, 1975; Williams and Stephenson, 1973; Stephenson *et al.*, 1974). Also, intensive examination of the biology (e.g., age, growth, condition, reproduction, recruitment, and feeding habits) of selected species should afford obvious clues of environmental alteration.

III. CURRENT STATE OF KNOWLEDGE

The macrofauna of the Bering Sea is well known taxonomically, and data on distribution, abundance, and feeding mechanisms for infaunal species are reported in the literature (Feder and Mueller, 1977; Feder *et al.*, 1976a; Filatova and Barsanova, 1964; Kuznetsov, 1964; Neiman, 1960; Rowland, 1973; Stoker, 1973; 1978). The relationship of specific infaunal feeding types to certain hydrographic and sediment conditions has been documented (Neiman, 1960, 1963; Stoker, 1973, 1978). However, the direct relationship of these feeding types to the overlying winter ice cover and its contained algal material and to primary productivity in the water column is not known. Preliminary insights as to the mechanisms that might integrate the water column and the benthos of the southeastern Bering Sea are discussed in Alexander and Cooney (1979).

The biomass and productivity of microscopic sediment-dwelling bacteria, diatoms, microfauna, and meiofauna have not been determined for the Bering Sea, and their roles should ultimately be clarified. It is probable that these organisms are important agents for recycling nutrients and energy from sediment to the overlying water mass (see Fenchel, 1969, for general review).

Until the initiation of OCSEAP investigations, the epifauna of the eastern Bering Sea had been little studied since the trawling activities of the Harriman Alaska Expedition (Merriam, 1904) and the voyages of the *Albatross*. Limited information can be obtained from the report of the pre-World War II king crab investigations (Fishery Market News, 1942) and from the report of the *Pacific Explorer*, fishing and processing operations in 1948 (Wigutoff and Carlson, 1950). Some information on species found in area is included in reports of the U.S. Fish and Wildlife Service, Alaska exploratory fishing expedition in 1948 (Ellson *et al.*, 1949) and the exploratory fishing expedition to the northern Bering Sea in 1949 (Ellson *et al.*, 1949). Neiman (1960) has published a quantitative report, in Russian, on the molluscan communities in the eastern Bering Sea. A phase of the research program conducted by the King Crab Investigation of the Bureau of Commercial Fisheries for the International North Pacific Fisheries Commissions included an ecological study of the eastern Bering Sea during the summers of 1958 and 1959 (McLaughlin, 1963). Sparks and Pereyra (1966) have presented a partial checklist and general discussion of the benthic fauna encountered during a marine survey of the southeastern Chukchi Sea during the summer of 1959. Their marine survey was carried out in the southeastern Chukchi Sea from the Bering Straits to just north of Cape Lisburne and west to 169°W. Some species described by them in the Chukchi Sea extend into the Bering Sea and are important there. An intensive survey of the southeastern Bering Sea is reported in Feder *et al.* (1978c) and Feder and Jewett (in press). Epifauna collected by them from 183 stations is described in terms of numbers and biomass trawled. They include data on the food of six species of benthic invertebrates and more than 13 species of fishes.

Crabs and bottom-feeding fishes of the Bering Sea exploit a variety of food types, benthic invertebrate species being most important (see Feder *et al.*, 1978c; Feder and Jewett, in press). Most of these predators feed on the nutrient-enriched upper slope during the winter, but they move into the shallower and warmer waters of the shelf of the southeastern Bering Sea for intensive feeding and spawning during the summer. Occasionally they exploit the colder northern portions of the Bering Sea shelf. This differential distribution is reflected by catch statistics which demonstrate that the southeastern shelf area is a major fishing area for crabs and bottom fishes. The effect of intensive predatory activity in the southern vs. the northern part of the shelf appears to be partially responsible for the lower standing stock of the food benthos in the southeastern Bering Sea (Neiman, 1960, 1963). Thus, it is apparent that bottom-feeding species of fisheries importance are exploiting the southeastern Bering Sea shelf, and are cropping what appear to be slow-growing species (Feder, unpublished observations; also see Section 5 of this report on clam growth) such as polychaetous annelids, snails, and clams. However, nektobenthic and pelagic crustacea such as amphipods and euphausids may grow more rapidly in the nutrient-rich water at the shelf edge, and may provide additional important food resources there (also see Alexander and Cooney, 1979 for a discussion of additional food resources available to the benthos by way of an uncoupled pelagic system over the mid-portion of the southeastern Bering Sea shelf).

Some marine mammals of the Bering Sea feed on benthic species (Lowry and Burns, 1976; Lowry, Frost and Burns, in press, a, b). Walrus feed predominantly on what appear to be slow-growing species of molluscs, but seals prefer the more rapidly growing crustaceans and fishes in their diets (Fay *et al.*, 1977). Marine mammals, although showing food preferences, are opportunistic feeders. As a consequence of the broad spectrum of food utilized and the exploitation of secondary and tertiary consumers, marine mammals are difficult to place in a trophic scheme and to assess in terms of energy cycling. Intensive trawling and oil-related activities on the Bering Sea shelf may have important ecological effects on infaunal and epifaunal organisms used as food by marine mammals. If benthic trophic relationships are altered by these industrial activities, marine mammals may have their food regimes altered.

Bibliographies of northern marine waters, emphasizing the Bering Sea are included in Feder and Mueller (1977) and Feder and Jewett (1978, and in press).

IV. STUDY AREA

A series of van Veen grab stations were occupied on a grid established in conjunction with the chemical, hydrocarbon, geological and trace metal program (Appendices 1.A, 1.B). Seventy-seven (77) stations were sampled (Appendix 1.B, Fig. 1); these stations extended from inshore to a maximum depth of approximately 1000 m. Only a few deep stations along the slope were occupied.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Benthic infauna were collected on two legs of a cruise on the R/V *Discoverer* (May-June 1975), three legs of a cruise on the R/V *Miller Freeman* in 1975 (Leg I - 16 August-3 September, Leg II - 12 September-26 September; Leg III - 3 October-24 October), and three legs of a cruise of the *Miller Freeman* in 1976 (March-June). To satisfy the objectives of the project, stations were selected over the entire study area, and these stations were occupied whenever a vessel was available.

Quantitative samples were taken with a 0.1 m^2 van Veen grab with bottom penetration facilitated by addition of 31.7 kg (70 pounds) of lead weight to each grab. Two 1.0 mm mesh screen doors on top of the grab permitted removal of undisturbed sediment samples by members of the hydrocarbon and heavy metals study groups (see appropriate OCSEAP Reports). In addition, the screen doors served to decrease shock waves produced by bottom grabs (see Feder *et al.*, 1973, for discussion of grab operation and effectiveness of the van Veen grab). Five to six replicate grabs were typically taken at all stations on all cruises (see discussion of optimum number of replicates that should be taken in a grab-sampling program in Feder *et al.*, 1973 and Feder and Matheke, 1979). Material from each grab was washed on a 1.0 mm stainless steel screen and preserved in 10% formalin buffered with hexamine. Samples were stored in plastic bags.

In the laboratory (Marine Sorting Center, University of Alaska, Fairbanks) grab samples from the collections of 1975 were rinsed to remove the last traces of sediment, spread on a gridded tray, covered with water and rough-sorted by hand. The material was then transferred to fresh preservative (buffered 10% formalin), and identifications made. All organisms were counted and wet-weighed after excess moisture was removed with absorbent towel. Analized samples from 1976 are reported and discussed by Haflinger (1978).

Criteria developed by Feder *et al.* (1973) to recognize Biologically Important Taxa (BIT) were applied to the data collected. By use of these criteria, each species was considered independently (items 1, 2 and 3 below) as well as in combination with other benthic species (items 4 and 5; adopted from Ellis, 1969). Each taxon classified as BIT in this study met at least one of the four conditions below.

1. It was distributed in 50% or more of the total stations sampled.

2 & 3. It comprised over 10% of either the composite population density or biomass collected at any one station.

4. Its population density was significant at any given station. The significance was determined by the following test:
    a. A percentage was calculated for each taxon with the sum of the population density of all taxa equalling 100%.
    b. These percentages were then ranked in descending order.
    c. The percentages of the taxa were summed in descending order until a cut-off point of 50% was reached. The BIT were those taxa whose percentages were used to reach the 50% cut-off point. When the cut-off point of 50% was exceeded by the percentage of the last taxon added, this taxon was also included.

Species diversity were examined by way of two Indices of Diversity:

1. Shannon-Wiener Index of Diversity:

$$H = -\Sigma\, p_i \log_e p_i \quad \text{where } p_i = \frac{n_i}{N}$$

n_i = number of individuals of species $i_1, i_2, i_3 \ldots i_x$
N = total number of individuals
s = total number of species

2. Simpson Index of Diversity:

$$s = \Sigma \frac{n_i}{n} \frac{n_{j-1}}{N-1}$$

3. Brillouin Index of Diversity:

$H = \frac{1}{N} (\log_{10}N! - \Sigma\log_{10}N_i!)$ where

N = total number individuals in all species

N_i = number of individual in the i^{th} species.

These indices were calculated for all stations sampled.

The Simpson Index is an indicator of dominance since the maximum value, 1, is obtained when there is a single species (complete dominance), and values approaching zero are obtained when there are numerous species, each a very small fraction of the total (no dominance). The Shannon-Wiener and Brillouin indices are indicators of diversity in that the higher the value, the greater the diversity and the less the community is dominated by one or a few kinds of species (see Odum, 1975, for further discussion and additional references).

All species taken by grab were coded according to the 10 digit VIMS system used for fauna collected in a benthic study in Chesapeake Bay (Swartz *et al.*, 1972); coding was suitably modified to conform to species collected in Alaskan waters (Mueller, 1975). Data were recorded on computer cards, and converted to magnetic tape. Data printout was accomplished by means of a special program written by James Dryden (Data Processing Services, Institute of Marine Science, University of Alaska). Data output consisted of a listing of stations occupied and replicates (samples) taken, a species-coding number list associated with a printout of Biologically Important Taxa (BIT) for all grab stations, and a series of station printouts [species collected, number of individuals, percentage of each species (number), biomass of individuals (per m^2 for all replicates per station), percentage of each species (biomass), Simpson Index, Shannon-Wiener Diversity Index]. All data were submitted to NOAA in NODC format.

Station groups and species assemblages have been identified using multivariate classificatory techniques. See Appendix 1.B for further details of methodology.

VI. RESULTS

The basic plan of operation for grab sampling was completed with little alteration. A systematic station grid was established in cooperation with other programs (physical and chemical oceanography, trace metal chemistry, hydrocarbon analysis, zooplankton), and a total of 77 stations were located on the established grid. Twenty-six (26) additional stations of opportunity were occupied in conjunction with the ice-edge studies on Leg I of the cruise of the R/V *Discoverer*. Although vessel time constraints did not permit sampling of the basic stations on a seasonal basis, it was possible to accumulate some seasonal samples from two time blocks - May through June and August through September.

The van Veen grab functioned effectively in the fine sediments of the Bering Sea, and typically delivered sample volumes of 10 to 14 ℓ. In stations that were sand or sand-gravel dominated, penetration was reduced. The surfaces of all samples, examined through the top door of the grab, were undisturbed as evidenced by the smooth detrital cover (see Feder *et al.*, 1973, for a review on use of the van Veen grab in soft sediments of the type found in the Bering Sea). The five to six replicates typically taken at each station appeared to be a minimal number as evidenced by qualitative examination of the station data (see Appendix Table I of Feder *et al.*, 1976a); fauna was obviously very patchy. The optimum number of replicates needed to properly sample the infauna of the Bering Sea has been tested by way of 10 replicate samples taken at selected stations (see Feder *et al.*, 1973; Feder and Matheke, 1979; Matheke *et al.*, 1976 for discussion on the optimum number of replicate samples needed in a grab-sampling program).

The size of screen chosen for the onboard washing process, 1.0 mm, was appropriate for the sediments sampled, and was the minimal size that could efficiently be used at most stations. A smaller size mesh would have greatly increased the overall shipboard washing time which in turn would have reduced the overall station coverage possible on each cruise.

Sixty-two (62) of the stations sampled were analyzed. Approximately 665 different infaunal organisms have been isolated with 464 distinct species identified (see summary of station data in Appendix 1.A). Members of 13 phyla were collected with the Annelida comprising the most important group with 180 species. Arthropoda were next in importance with 120 species, and Mollusca next with 109 species. Other groups were less important (Tables II and III, and Appendix Table III in Feder *et al.*, 1976a).

The two diversity indices, Simpson and Shannon-Wiener, calculated for 27 of the stations occupied in 1975 are summarized in Table IV of Feder *et al.* (1976a). The indices calculated for the 62 stations included in this report are included in Appendix 1.B. No statements can be made at this time concerning the importance of these indices. When data for all stations, inclusive of 1976 infaunal data are available, some overall generalizations may be possible. Preliminary analysis of this data are included in Haflinger (1978).

Utilization of the criteria for Biologically Important Taxa delineated 121 species for the 1975 data (see Appendix Table 3 in Feder *et al.*, 1976a). Thirty-eight (38) of the BIT were identified as important by way of biomass at one or more stations. Some of these species that were well distributed throughout the study area were *Nucula tenuis* (clam), *Yoldia hyperborea* (clam), *Macoma moesta alaskana* (clam), *Clinocardium ciliatum* (cockle), *Diamphiodia craterodmeta* (brittle star), and *Echinarachnius parma* (sand dollar). These species probably have trophic importance in their particular localities.

The continental shelf region of the southeastern Bering Sea can be classified into five station groups based on multivariate analysis of infaunal distribution. Three large station groups lie in adjacent bands extending from the Alaskan coast to the shelf break, roughly paralleling the bathymetry. Two smaller groups occupying positions at the head of Bristol Bay and off Nunivak Island were identified. Stations in the northwestern section of the study area (near the Pribilof Islands) show no strong affinity to the major station groups.

Fourteen major biocoenoses identified on the basis of species distribution show strong correlation with the spatial positioning of station groups. Spatial patterning of these species groups is described on the basis of their representation at station groups. Characteristic differences in trophic structure between station groups are attributed to the effects of storm-induced turbulence in nearshore environments and periodic intensive input of organic carbon in the mid-shelf region.

The feeding methods used by 56 of the species collected are included in Appendix 1.B, these species are components of the species groups formed by a cluster analysis performed by Haflinger (Appendix 1.B). The data are compiled from the literature and from personal observations (Feder *et al.*, 1973; Feder and Mueller, unpublished data and 1975, Feder and Matheke, 1979, and interpretations). Some of the species probably utilize two or more feeding methods, and such multiple feeding methods, where known, are included in the table. The predominant feeding methods utilized by species at each station have not been determined as yet. It is presumed that the methods used will tend to vary with local conditions, and be reflected to a certain extent by the substrate type at each station.

Clam Studies

Most of the bivalve molluscs collected in large numbers by grab (e.g., *Nuculana fossa, Nucula tenuis, Yoldia amygdalea, Tellina lutea, Macoma calcarea, Spisula polynyma*) have been examined for age-growth characterristics. These data are presented in Section 5.

VII. DISCUSSION

Performance of the 0.1 m^2 van Veen Grab

The van Veen grab was a suitable instrument for sampling most of the stations of the shallow shelf of the Bering Sea; the grab typically collected moderate volumes of sediment (10 to 14 ℓ). Considerably smaller volumes were found at sandy stations. Lie (1968) indicates that 1 cm penetration of the 0.1 m^2 van Veen grab will collect 1 ℓ of sediment, and states that a digging depth of at least 4 cm should be attained to ensure adequate representation of the fauna. He was able to accomplish this on all muddy bottoms; a situation that was also true for our grab sampling activities in the Bering Sea at stations with mud bottom.

Number of Grab Samples Per Station

One of the primary objectives of the study was a qualitative inventory of dominant species. Since sufficient ship time was available to cover the station grid, five to six replicate samples were taken per station to ensure adequate quantification per station. Three replicates were adequate to sample the most abundant species in the soft sediments of Port Valdez, Prince William Sound, Alaska (Feder *et al.*, 1973). Recruitment of numbers of individuals in subsequent samples represented members of less abundant species (Feder *et al.*, 1973). The general applicability of the Port Valdez analysis to the Bering Sea has been tested using 8 to 10 replicates at a variable number of selected stations with the grab-sampling simulation program developed by Feder *et al.*, (1973). Five replicate samples per station have been suggested by Longhurst (1964) and Lie (1968) and further corroborated by the investigations of Feder *et al.* (1973) and Feder and Matheke (1979). Thus, five to six grabs per station should be adequate.

Station Coverage

The intensive OCSEAP grab-sampling program, now completed, on the southeastern Bering Sea shelf is the most comprehensive one carried out by an American research group in the area to date. Somewhat parallel earlier studies by the Soviet Union are available in the literature for comparative purposes (see Alton, 1974, for review of Soviet literature; also Hood, 1973). Although the latter studies were broad, the bases for calculations used by them (i.e., the station data--number of replicate samples per station, the species taken per replicate, the number of individuals of each species taken per replicate, and the biomass for each species per replicate) are unavailable. Thus, precise quantitative comparisons are not possible. The study of the Bering Sea by Stoker (1978) partially overlaps the present sampling grid, but more intensively investigates the northeastern Bering sea and southern Chukchi Sea.

Since grab station coverage by our investigation was only as intensive as allotted ship time and weather conditions would permit, it is recognized that vast unsampled areas exist in the study area. It is possible, but not probable, that some unsampled regions support significant populations of hitherto uncollected benthic species.

Counterclockwise water circulation exists in the surveyed region, with an increase in average current velocity with an increase in depth (Hebard, 1959). Bottom sediments have been found to vary from fine mud in the western part to dark and coarse sand inshore (McLaughlin, 1963; Section 2). Access to these and other appropriate environmental data should ultimately make it possible to understand larval dispersion and settlement as well as adult distribution of benthic species on the shelf (see Sections 2 and 3 for data and discussions on distribution of selected infaunal species).

Species Composition of the Stations

The composition and general distribution of benthic infaunal species in the projected lease areas is now well documented [present investigation and Soviet surveys: see Alton (1974), for review; see Appendix Table I in Feder *et al.* (1976a)]. Members of the major marine phyla were collected in all investigations. Polychaetous annelids were the most important infaunal group in terms of numbers of species collected by the grab-sampling program. A variety of infaunal groups contributed noticeably to the biomass at the grab stations (see tabulated data in Feder *et al.*, 1976a; data submitted to NODC; Appendix B).

Diversity Indices

It is generally accepted that an altered environment will result in changes in both numbers of species and population densities of these species (Pearson *et al.*, 1967). Thus, examination of species diversity can often serve as a basis for comparison in the event of environmental alteration. In order to avoid subjective appraisal, a quantitative measure of diversity must be used. Such a measure should typically consider the number of species present, as well as the density of each species. Various diversity indices are available and at least two different types should be used to give the greatest insight into the faunal conditions present (Lloyd *et al.*, 1968). The indices included in this report, Simpson, Shannon-Wiener, and Brillouin are complementary to each other since the former reflects dominance of a few species and the latter two are weighed in favor of rare species. The calculated indices (Appendix 1.B; Appendix Table I in Feder *et al.*, 1976a) should be interpreted with caution, and no comparisons made until more data are available for each station.

Biologically Important Taxa

As suggested by Lie (1968), "Most animal communities are so complex and rich in species that it is necessary to make a choice of the species that supposedly are most important to the communities and subject them to detailed analysis". Such species have been variously termed "characterizing species" (Thorson, 1957), and "ecologically significant species" (Ellis, 1969). The criteria used for selection of such species vary; criteria used in this investigation for distinguishing infaunal taxa of biological importance are listed in the section on Methods. See Feder *et al.* (1976a) for compilation of all of the species designated as Biologically Important Taxa, and Feder *et al.* (1973) for further discussion on the application of this concept to species in Port Valdez.

The initial printout of biologically important taxa was large. Additional assessment of this list was necessary in order to reduce the number of taxa to a size that could be more readily used in computations essential to assessment of species groupings. Nevertheless, it is apparent that a large number of species, occupying diverse ecological niches, are available for monitoring if industrial activity in the southeastern Bering Sea is initiated.

Feeding Methods

Some information is discussed in Feder *et al.* (1976a) and Haflinger (1978; Appendix 1.B) on feeding methods used by some of the infaunal species collected. Feeding methods of species tabulated for the northeast Gulf of Alaska (NEGOA) offer comparative information, and are tabulated in Feder *et al.* (1976b) and Feder and Matheke (1979). However, the lack of a substantial data base for Bering Sea infaunal feeding biology dictates the urgency of support of descriptive and experimental work on selected species from the benthos there.

Of the major epifaunal biomass components in the Bering Sea (i.e., king crab, snow crab, and the sea star *Asterias amurensis*), only the feeding habits of the king crab have been examined intensively. McLaughlin and Hebard (1961) determined percent frequency of occurrence for food items of male and female Bering Sea king crab. Primary food items were molluscs (76.9%, male; 60.6%, female), echinoderms (48.5%, male; 35.6%, female), and decápod crustaceans (26%, male; 19.4%, female). Polychaetes, algae, and other crustaceans followed, in descending order of importance. Feeding was not significantly different between the sexes. Feniuk (1945) found molluscs, crustaceans, and polychaetes, in that order, to be the important food items of king crabs from the west-Kamtchatka shelf. Results presented in Feder and Jewett (in press) match those of McLaughlin and Hebard (1961) as well as Takeuchi (1967), and indicate that echinoderms are an important food resource for king crab in the Bering Sea. The data of Feder *et al.* (1978a, c) and Feder and Jewett (in press) show that *P. camtschatica* feeds primarily on the cockle *Clinocardium ciliatum*, the small snails *Solariella* spp., the nut shell *Nuculana fossa*, the polychaete *Cistenides* sp. and brittle stars of the family Amphiuridae in the Bering Sea region examined.

Food habits of *Chionoecetes opilio* are known for the Sea of Japan (Yasuda, 1967). Abundant food items there are *Ophiura* spp., *Chionoecetes opilio elongatus*, some protobranch clams, and the sea star *Coscinodiscus*; common food items included the polychaete worm *Aphrodita*, the shrimp *Pandalus*, other decapods, the snails *Natica, Buccinum, Neptunea*, and some protobranch clams including *Nuculana*. Bering Sea snow crab feeding habits (Feder and Jewett, in press) were quite dissimilar to those in the Sea of Japan, and polychaetes were a major food item rather than a minor element as in the Sea of Japan; ophiuroids were also an important food item (Feder *et al.*, 1978a, c). No Bering Sea snow crab was found feeding on other snow crab.

The sea star *Asterias amurensis* is apparently a great feeding generalist (Feder and Jewett, in press). Food items were from seven phyla with no single item being used by more than 17.1% of the sea stars examined. In contrast, the sea star *Leptasterias polaris ascervata* fed solely on *Clinocardium*. This cockle must be quite abundant, although apparently patchy in distribution, since it is an important prey item of *P. camtschatica* and *A. amurensis* as well as *L. p. ascervata* (see Section 2 for distribution and abundance data for *Clinocardium*; also see infaunal data on file with NODC).

Bering Sea flatfishes commonly feed on pelecypods (clams and cockles) (Pereyra *et al.*, 1976). Most pelecypods may be using a combination of suspension and deposit feeding methods (Rasmussen, 1973; Feder, unpublished data) with one feeding method dominant and the other employed occasionally. Thus, the addition of pollutants to the sediments may affect pelecypods not usually considered as deposit feeders (for example, *Clinocardium* and *Cyclocardia*), and will ultimately impact their predators. Pelecypods are fed on directly by king crab, snow crab, and Pacific cod, as well as flatfishes, and these mollusks are of unquestionable importance as a major food resource in the Bering Sea.

Clam Studies in the Bering Sea

As indicated above, bivalves are important food resources for king crab and several species of demersal fishes in the Bering Sea (Feder *et al.*, 1978c; Feder and Jewett, 1978). Information on distribution, growth, age, recruitment, and mortality rates of bivalves important as food resources for benthic predators will be useful to future studies of secondary production on the bottom (Sections 2, 4, 5). Species examined in these studies are *Nuculana fossa*, *Nucula tenuis*, *Yoldia* spp., *Tellina lutea*, *Macoma calcarea*, *Clinocardium ciliatum*, *Cyclocardia crebricostata*, and *Spisula polynyma*. Age, growth, and mortality data for *Macoma calcarea* and

Clinocardium ciliatum from the Bering Sea are also available in Stoker (1978) and A. J. Paul (unpublished data). See Section 5 for further discussion.

VIII. CONCLUSIONS

Seventy-seven widely dispersed permanent stations and seven stations of opportunity were established. These stations represent a reasonable nucleus around which a monitoring program can be developed. Sixty-two of these stations were analyzed for this report (Appendix 1.B).

The sampling device chosen, the van Veen grab, functioned effectively in all weather, and adequately sampled the infauna at stations with a sandy-mud or mud bottom. Poor penetration occurred at stations where the substratum was sandy or gravelly. Since coarse sediments are more characteristic of the Bering Sea than the Gulf of Alaska (Feder and Matheke, 1979) reduced volumes were found in most grabs throughout the station grid. However, assessment of grab volumes obtained on most of the stations indicates that the majority of the stations can be considered quantitative (i.e., grab volumes greater than 5 ℓ).

The general patchiness of many components of the Bering Sea fauna suggests that the five or six replicate samples taken per station are the minimum number that should be taken.

There is now a satisfactory data base for the infaunal invertebrate species for that portion of the Bering Sea shelf grid investigated. Approximately 665 different infaunal and slow-moving epifaunal organisms have been determined with 464 distinct species identified. Thirteen (13) marine phyla are represented in the collections. The important groups, in terms of number of species, are the Annelida (180 species), Arthropoda (120 species), Mollusca (109 species), and Echinodermata (17 species). It is probable that all infaunal and slow-moving epifaunal species with numerical and biomass importance have been collected during the intensive sampling program of the spring, summer, and early fall of 1975. It is assumed that only rare species will be added to the list in the future (see Feder *et al.*, 1978c for data and discussion of epifauna of the southeastern Bering Sea).

No analyzed data are available to test for seasonal fluctuations in species by station. The continuing series of cruises in the spring, summer and early fall of 1975 have made available some seasonal samples; however, limited funding made it impossible to analyze these data for the Final Report. Much of the data are stored on magnetic tape. Some mid-winter quantitative grab data are available from stations within the study area by way of investigations of Fay *et al.* (1977) and Stoker (1973, 1978). Additional qualitative information on distributions of infaunal species in the study area at various periods can be found in the Soviet literature (see Alton, 1974 for review).

The diversity indices (Simpson, Shannon-Wiener and Brillouin) included in the 1976 Annual Report (Feder *et al.*, 1976a) and Appendix 1.B, are complementary to each other since the former reflects dominance of a few species and the latter two are weighted in favor of rare species. These indices should be interpreted with caution until more data are analyzed (see data and discussion in Appendix 1.B).

Criteria established for Biologically Important Taxa (BIT) have delineated 121 species (Feder *et al.*, 1976a). Representative members of the BIT should be the organisms most intensively studied in further investigations in the southeastern Bering Sea.

Information on feeding biology of 180 species collected by grab has been compiled. Most of this information is from literature source material (see Matheke *et al.*, 1976; Feder and Matheke, 1979 for literature citations); it is recommended that experimental work on feeding biology for selected species be encouraged. Some qualitative assessment of the distribution of some infaunal species, their feeding methods, and the type of sediment present where they occur is included in the 1976 Annual Report (Feder *et al.*, 1976a), Appendix 1.B, and Sections 2 and 3. Analysis of sediments collected at each benthic station is completed (see Hoskin, 1978; Appendix 1.B; and Sections 2 and 3 for further comments on the relationship of sediment to biota).

Seasonal ice cover over much of the Bering Sea shelf, indication of primary productivity several meters over the bottom, an apparent uncoupled carbon flow over the mid-shelf (Alexander and Cooney, 1979), and seasonal upwelling in Bristol Bay were events that suggest unique variations in nutrient cycling and carbon flux. Explanations for benthic community structure in the Bering Sea should be sought, in part, in the unique variations of the ecosystem there. "A description of the structural components of that ecosystem and estimates of the rates at which the underlying processes operate will lead...to increased knowledge of such systems in general,..." (Hood, 1973). The shallow shelf benthic system has been examined initially with multivariate techniques applied to species present in an attempt to cluster or aggregate groups of stations and species. Community structure must be further analyzed by examining trophic interactions of resident species within clusters. Integration of available infaunal and epifaunal (Feder *et al.*, 1978c) data in conjunction with environmental parameters are essential to a complete understanding of the southeastern Bering Sea benthic system.

IX. NEEDS FOR FURTHER STUDY

1. Although the van Veen grab is satisfactory for use in the Bering Sea at stations with soft sediments, it is less satisfactory at stations with coarse fractions. Penetration of the grab was often not sufficient at the latter stations, and large infaunal species may have been missed by the grab. The use of a pipe dredge in 1976 collected some species that were deeper in the sediment (Section 2). However, use of a box core sampler at some of these stations is indicated, and is suggested for the future.

2. The number of grab stations occupied was dictated by available ship time and funding essential to complete processing of the samples. Thus, a relatively small number of additional stations should be occupied in the future to develop some baseline data for the unsampled areas. Additional funds should be made available to complete the additional stations.

3. Seasonal data on an approximately quarterly basis would be useful. It is especially recommended that under-ice samples be obtained when

Coast Guard icebreaker capabilities are increased. Annual data are essential in view of the extreme warming cycle that has occurred in the Bering Sea since the 1975-76 samples were collected. Presumably larval survival and recruitment have differed considerably in the warm years of 1978 and 1979, as compared to 1975-76. No infaunal data are available for these years.

4. Selected members of the Biologically Important Taxa (BIT) should be chosen for intensive study as soon as possible so that basic information will be available to a monitoring program. Specific biological parameters that should be examined are reproduction, recruitment, growth, age, feeding biology, and trophic interactions with other invertebrates and vertebrates.

5. The advantage of the cluster analysis technique is that it provides a method for delineating station groups that can be used as a basis for developing monitoring schemes and delimiting areas that can be used for intensive studies of feeding interactions. It is obvious that food webs will vary in areas encompassing differing species assemblages. An inaccurate or even erroneous description of the shelf ecosystem could occur if trophic data collected on species from one station cluster (with its complement of species) is loosely applied to another area encompassing a totally different station cluster (with its differing complement of species). Thus, development of clustering and other multivariate techniques should be refined to be certain that the best methodology is available to monitoring programs in the Bering Sea.

6. A closer integration of infaunal data with geological parameters is essential to better comprehend faunal-sediment interactions. It is recommended that in the future infaunal and geological data be collected simultaneously.

7. The extensive trawl program in conjunction with the National Marine Fisheries Service permitted complete coverage of the benthos for epifaunal invertebrates. Considerable effort is still needed to complete these studies, and the following is recommended: maps of distribution and abundance for selected species, calculations of diversity indices,

derivation of a list of Biologically Important Taxa, application of multivariate techniques to groups of species and stations, and further assessment of the results of food studies. Additional needs for the future in trawling activities are the development of a monitoring plan as well as additional trawl data on a seasonal basis.

8. Additional food data are essential; the OCSEAP-sponsored invertebrate studies of Feder and associates, did not include trophic investigations as major portions of their projects. However, present data on trophic interaction between organisms of the benthos in the Bering Sea (Feder, current Annual Report; Smith *et al.*, 1978) suggest that a base may now be available to initiate a modeling effort for the Bering Sea, or at least to initiate workshops to assess the possibilities that exist for such an effort.

APPENDIX 1.A

SUMMARY OF DATA COLLECTED BY VAN VEEN GRAB AT 60 STATIONS IN THE SOUTHEASTERN BERING SEA

APPENDIX TABLE 1.A

BERING SEA BENTHIC GRAB DATA, CRUISES 808 AND 817

Station-sample listing

Cruise	Station	Tot Cnt	Tot WWgt	Cnt/m^2	WWgt/m^2	Grabs
808	1	1785	363.001	3570	726.002	5
808	2	863	295.050	2877	983.500	3
808	3	565	20.238	1130	40.476	5
808	4	350	201.416	1167	671.387	3
808	5	138	142.907	690	714.535	2
808	6	345	462.651	690	925.302	5
808	7	159	185.438	227	264.911	7
808	8	1962	16.228	3924	32.456	5
808	9	906	142.025	1294	202.893	7
808	10	381	83.491	762	166.982	5
808	11	522	14.096	1044	28.192	5
808	12	1127	16.646	2254	33.292	5
808	13	328	21.596	547	35.993	6
808	14	758	16.253	1516	32.506	5
808	15	294	21.132	588	42.264	5
808	16	337	11.559	674	23.118	5
808	17	436	15.244	872	30.488	5
808	18	816	41.856	1632	83.712	5
808	19	2083	134.444	4166	268.888	5
808	20	1311	55.879	2622	111.758	5
808	22	780	134.097	709	121.906	11
808	23	210	82.179	420	164.358	5
808	24	789	231.509	1973	578.772	4
808	25	1439	57.756	2056	82.509	7
808	27	1076	42.009	2152	84.018	5
808	28	2197	1210.025	4394	2420.050	5
808	29	2227	167.082	4454	334.164	5
808	30	313	15.638	626	31.276	5
808	31	1139	23.037	1035	20.943	11
808	35	630	40.933	1260	81.866	5
808	36	589	22.460	1178	44.920	5
808	38	306	319.764	612	639.528	5
808	39	982	4.678	1964	9.356	5
808	40	1487	10.307	2478	17.178	6
808	41	3125	118.080	4464	168.686	7
808	42	567	55.456	1134	110.912	5
808	43	1511	68.747	3022	137.494	5
808	44	209	6.817	2090	68.170	1
808	45	1824	66.495	2606	94.993	7
808	49	346	11.514	577	19.190	6
808	57	1753	28.370	2504	40.529	7
808	59	971	57.788	2428	144.470	4
808	60	478	125.513	531	139.459	9
808	924	322	141.788	644	283.576	5

APPENDIX TABLE 1.A

CONTINUED

Cruise	Station	Tot Cnt	Tot WWgt	Cnt/m^2	WWgt/m^2	Grabs
808	932	94	5.769	470	28.845	2
808	935	1203	49.401	2406	98.802	5
808	937	783	38.198	1566	76.396	5
808	939	625	96.436	1250	192.872	5
808	941	418	93.820	836	187.640	5
808	942	328	82.989	820	207.472	4
808	953	155	10.503	1550	105.030	1
808	999	141	9.951	1410	99.510	1
817	49	2340	50.003	4680	100.006	5
817	55	1665	53.005	3330	106.010	5
817	70	527	58.854	1757	196.180	3
817	71	1354	87.937	2708	175.874	5
817	72	796	61.190	1592	122.380	5
817	73	367	7.145	734	14.290	5
817	82	560	58.372	1120	116.744	5
817	83	1141	53.117	2282	106.234	5

Total number of stations: 60

APPENDIX 1.B

A NUMERICAL ANALYSIS OF THE DISTRIBUTION OF THE BENTHIC INFAUNA OF THE SOUTHEASTERN BERING SEA SHELF. M.S. THESIS

BY KARL E. HAFLINGER

A NUMERICAL ANALYSIS OF THE DISTRIBUTION OF THE BENTHIC INFAUNA OF THE SOUTHEASTERN BERING SEA SHELF

A

THESIS

Presented to the Faculty of the
University of Alaska in partial fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE

By
Karl E. Haflinger, B.S.
Fairbanks, Alaska
December 1978

ABSTRACT

The continental shelf region of the southeastern Bering Sea may be classified into five provinces (station groups) based on infaunal distribution. These large station groups lie in adjacent bands extending from the Alaskan coast to the shelf break, roughly paralleling the bathymetry. Two smaller groups occupying positions at the head of Bristol Bay and off Nunivak Island were identified. Stations in the northwestern section of the study area (near the Pribilof Islands) show no strong affinity to the major station groups.

Fourteen major biocoenoses identified on the basis of species distribution show strong correlation with the spatial positioning of station groups. Spatial patterning of these species groups is described on the basis of their representation at station groups. Characteristic differences in trophic structure between station groups are attributed to the effects of storm-induced turbulence in nearshore environments and periodic intensive input of organic carbon in the midshelf region.

ACKNOWLEDGEMENTS

I wish to express gratitude to Mr. George Mueller and the staff of the Marine Sorting Center at the University of Alaska for their diligence in the identification of organisms used in this study and to Cydney Hansen and the personnel of the IMS Data Processing group for their assistance in the computer studies. I also wish to thank Drs. V. Alexander, S. J. Harbo, Jr., and D. B. Hawkins for their thoughtful reviews of the manuscript, and Dr. G. D. Sharma for permission to use the unpublished data included in Figure 22 of this appendix.

Special appreciation is extended to Mr. Grant Matheke for many provocative discussions on the subject of benthic community studies and for the use of many of his computer programs. I especially wish to thank Dr. Howard Feder for his continued support and encouragement in the many areas in which they were needed.

This research was supported by funds from NOAA as part of the OCSEAP program, Research Unit #5.

INTRODUCTION

Initial surveys of the benthic macrofauna of the southeastern Bering Sea have been carried out by both Russian and American scientists as part of several expeditions to the area, back to 1932 (Alton, 1974). This work has resulted in a basic knowledge of the organisms present and an overview of standing stocks (Neiman, 1963; Semenov, 1968; Stoker, 1973, 1978). Much of the work either cannot be considered quantitative (in the sense that only one sample was taken at each station), or is based on a sampling interval too large to be valid for community studies. The work of Stoker (1973, 1978) was of sufficient intensity to facilitate community description but was concentrated in the northern shelf areas.

The purpose of the present study was to delineate provinces on the basis of the distribution and abundance of major infaunal species found on the southeastern Bering Sea shelf. In addition, an attempt has been made to distinguish species assemblages also defined on the basis of distribution and abundance information.

A traditional manner of approaching benthic community studies has been to search for groups of organisms sharing coincident ranges and to find groups of stations characterized by a similar fauna. Such approaches have often considered only dominant species (Peterson, 1913; Thorson, 1957; Neiman, 1963, Semenov, 1964) simply because difficulties in handling large sets of data prohibited the inclusion of less common forms in ecological studies. Numerical approaches to the problem of community delineation have been developed with the advent of high speed computers. These approaches are now useful in situations requiring the digest of large numbers of observations, a situation generated by studies such as this in which many rare species are considered.

Statistical methods designed to resolve problems in classification are now commonly used by benthic ecologists (Field, 1970; Lie and Kisker, 1970; Stephenson, Williams, and Lance, 1970; Stephenson, 1973; Williams and Stephenson, 1973). Of these methods, cluster and discriminant analysis deal directly with the problem of classification. "Ordination" techniques such as principal coordinates and principal components analysis are also useful in this capacity. Other multivariate statistical methods, primarily variants of factor analysis, are often used in addressing both the problems of classification and the exposition of underlying sources of variation.

Detailed studies of both species groups (assemblages) and station groups (provinces) may be employed as checks on postulated group boundaries. If such groups are valid, then evidence supporting the hypothesis of their existence should be forthcoming in the form of contrasting biotic and/or abiotic properties associated with the groups. In this study, examinations of such properties have been confined to those associated with station groups, with an emphasis on substrate types, diversity, and trophic structure found within groups.

The definition of station groups via the techniques mentioned is formally independent of the definition of species groups and vice-versa. A third area of study--that of the correlation between species and station groups--relates the two. Such a study has been approached informally here in the course of drawing both species and station group boundaries, although a rigorous mathematical approach to the problem of station group-species group relations was not undertaken.

STUDY AREA

The study area encompasses the southeastern Bering Sea continental shelf from St. Matthew Island south of the Alaska Peninsula. The station grid occupied during three cruises (NOAA Ship *Discoverer*, spring 1975; NOAA Ship *Miller Freeman*, fall 1975; NOAA Ship *Miller Freeman*, spring 1976) is presented in Figure 1. Station positions and associated water depths are listed in Appendix I. Station locations extend from shallow areas near the Kuskokwim River and the head of Bristol Bay to the shelf slope, with a maximum depth of 1,500 m.

The shelf topography is remarkable for its width (450-500 km in the study area), shallowness (generally <150 m), and gentle slope (average slope = 0.0024%). The bottom sediments of the southeastern Bering Sea shelf have been described by Sharma (1974, 1975), Sharma *et al.* (1972), and Hoskin (1978). Two major depositional environments are evident on

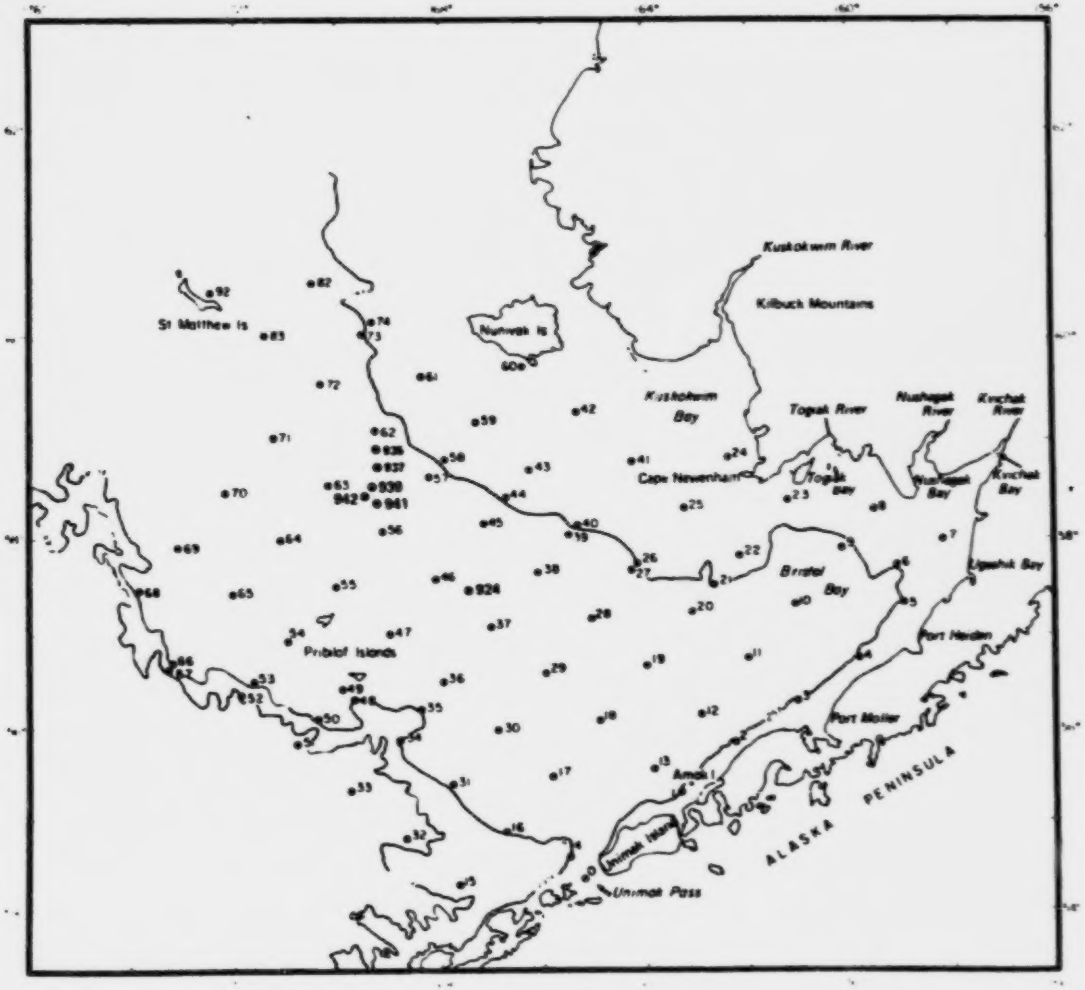

Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 1. Study area used in Bering Sea infaunal studies.

the basis of particle size analysis--an inner and an outer continental shelf area. The inner shelf region is characterized by a preponderance of fine to coarse sand and gravel while the shelf sediments are a clay, silt, and sand mixture. The apparent trend is one of decreasing mean size with increasing water depth. To account for this trend, Sharma (1975) postulates a suspension of bottom sediments resulting from long wave action, an effect that would decrease with increasing water depth. The decreasing long wave action is then thought to be reflected in the increased deposition of fine-grained sediments in the deeper areas.

Much of the shelf is ice-covered during the winter and an intensive bloom is associated with the retreat of the ice in the spring (McRoy and Goering, 1972; Alexander, 1978). Further input of organic carbon to the shelf-based marine system is supplied by several rivers draining into the area (especially the Kvichak, Nushagak, and Kuskokwim rivers) and from seagrass beds located in several large estuaries along the Alaskan Peninsula.

The physical oceanography of the Bristol Bay area has been reviewed by Coachman and Charnell (1977). Three water masses are discernible: (a) a warm (3° to 4°C at its coldest) and saline (32 to $33^{\circ}/_{\circ\circ}$) Bering Sea source water with origins in the deep Bering Sea and the Alaskan Stream via Unimak Pass; (b) a colder (-1° to +2°C in June) and slightly less saline mass of resident shelf water exhibiting little salinity stratification but usually markedly stratified with respect to temperature in summer; and (c) a nearshore water mass with a low salinity attributable to coastal runoff and often stratified with respect to both temperatures and salinity in the deeper layers.

Circulation over the shelf has been described by Takenouti and Ohtani (1974) and generally verified by the work of Coachman and Charnell (1977). Deep Bering Sea or Alaskan Shelf water tends to move onto the shelf in central and southern Bristol Bay and then towards the head of the bay paralleling the Alaska Peninsula. Currents over the main shelf are to the northwest, or roughly parallel to the bathymetry. T-S diagrams presented by Coachman and Charnell (1977) suggest that Bering Sea source water interacts with resident shelf water along a front extending 100 to 150 km inshore from the shelf break. Evidence of penetration of this water further inshore is obscured by the relatively small volumes of source water involved.

METHODS

COLLECTION AND TREATMENT OF SAMPLES

Six replicate bottom samples were collected at most stations using a 0.1 m^2 van Veen grab. The performance of the grab was highly dependent on substrate, being least satisfactory in the inshore areas with coarse sand bottoms. Station averages for grab volumes ranged from 1 to 14 liters (Table 1).

The grab contents were washed over a 1 mm screen and all invertebrates left on the screen were preserved in a 10% buffered formalin solution. Samples were taken to the Marine Sorting Center at the University of Alaska, Fairbanks, for identification and weighing. Samples analyzed for the study reported here were collected May-August 1975. Samples collected in the spring of 1976 are analyzed and discussed in Haflinger (in press).

DATA ANALYSIS

Type and Quality of Available Data

The raw data included both the numbers of individuals of all taxa found and their wet weights. These figures were standardized to the square meter and from this information station totals and means were derived. An example of the results of this procedure is shown for Station 7 in Appendix II.

Four hundred and sixty-four (464) distinct species were identified; in addition, as only fragments of organisms were commonly encountered, many identifications were necessarily made to taxonomic levels more general than that of species. To use the multivariate techniques mentioned earlier, a significant reduction in the number of species to be considered was necessary,

Table 1. Average grab volumes (in liters) from Bering Sea benthic stations.

Station	Average Volume	Station	Average Volume	Station	Average Volume	Station	Average Volume
1	6	17	14	38	2	65	9
2	10	18	7	39	3	924	5
3	4	19	6	40	3	935	5
4	2	20	4	41	8	937	9
5	8	22	5	42	1	939	11
6	4	23	5	43	7	941	12
7	8	24	3	45	8	942	12
8	4	25	5	49	8	47	3
9	7	27	6	57	5	55	3
10	5	28	8	59	7	70	12
11	3	29	9	60	6	71	10
12	3	30	12	61	4	72	9
13	5	31	7	62	3	73	7
14	5	35	6	63	12	82	12
15	11	36	10	64	14	82	9
16	11	37	2				

hence only those occurring at five or more stations were included in the numerical analysis. One hundred and eighty (180) such species were found. Representation by phyla of both these 180 species and the original 464 species is given in Table 2. A listing of the names of the 180 species may be found in Appendix III.

The data base consisted of the mean number of individuals of each particular species and the corresponding mean wet weight, each mean being that calculated for a particular station. Although these mean figures were subsequently regarded as fixed values, they are obviously estimates and have an associated sampling variance. A review of the data presented in Appendix II illustrates the sort of between-sample (grab) variance encountered. This source of variance is generally ignored in benthic community studies. Feder *et al.* (1978) have performed a nested ANOVA based on station groups divided into stations and then samples (as randomly chosen subgroups), using diversity, total numbers of individuals per m^2, and total wet weight per m^2 as sample variables for several different runs. Their results suggest that while the largest single source of variation is the between-sample variance, the between-station and between-station-group differences are still significant.

This approach does not directly address the problem of between-sample variation, for only a single variable was chosen to represent each sample while the actual number of variable equals the number of species. A multivariate analysis-of-variance would seem a more appropriate solution, but problems arise from both the large number of variables and the presence of many zeroes in the data set. For these reasons no attempt has been made to incorporate such an analysis in this study.

Cluster Analysis and the Delineation of Station Groups

Several different numerical methods were used to define station groups: an agglomerative, polythetic cluster analysis, principal coordinates analysis, and principal components analysis. These methods are described below; summaries appear in an appendix of numerical methods, Appendix IV.

Clear introductions to the techniques of cluster analysis may be found in the works of Pielou (1977), Williams and Lance (1977), and others. More

Table 2. Number of species collected and number used in analysis

Phyla	Number of Species Found	Number of Species Used in Numerical Analysis
Cnidaria	2	0
Annelida	194	80
Mollusca	117	41
Arthropoda	119	45
Echiuroidea	1	0
Sipunculida	4	2
Ectoprocta	4	0
Priapulida	1	1
Brachiopoda	1	1
Echinodermata	17	8
Urochordata	4	2

extensive discussions of the subject are presented in Gower (1969), Blackith and Reyment (1971), Anderberg (1973), Clifford and Stephenson (1975), and Hartigan (1975). In the present study, fusion procedures were used with a stored similarity matrix approach. The Czekanowski and Canberra metric dissimilarity coefficients were chosen to act as complementary distance measures. Their formulas are:

Czekanowski coefficient

$$d_{jk} = \frac{\sum_{i=1}^{n} |x_{ij} - x_{ik}|}{\sum_{i=1}^{n} (x_{ij} + x_{ik})}$$

Canberra metric coefficient

$$d_{jk} = \frac{1}{n} \sum_{i=1}^{n} \frac{|x_{ij} - x_{ik}|}{(x_{ij} + x_{ik})}$$

where x_{ij} represents the value for the ith species at the jth station.

A separate clustering effort was undertaken for each of the similarity measures. The advantage to clustering several times using differing distance measure is that different measures admit varying degrees of influence on the part of the dominant species. Since, in the computation of the Canberra metric measure, a dominant species affects but one of a series of fractions, the Canberra metric-based interpretation is less influenced by the dominant species than is an interpretation based on the Czekanowski coefficient. Another means of reducing the effect of dominance is the transformation of raw data. Many investigators in this field have found that logarithmic or square root transformations are necessary to produce useful results. In the present study all techniques were run with data that had been transformed to the natural logarithm, as preliminary results proved the need for transformations to produce interpretable results.

A general model for updating a stored distance matrix after each stage in the cluster analysis has been given by Lance and Williams (1977) as:

$$d_{hk} = \alpha_i d_{hi} + \alpha_j d_{hj} + \beta d_{ij} + \gamma |d_{hi} - d_{hj}|$$

where d_{hi} and d_{hj} represent the appropriate calculated distances between the two entities that have been fused (the ith and jth) and the third (hth) entity. The entity formed by the fusion of the ith and jth entities is denoted by the subscript k. The parameters α_i, α_j, β, and γ determine the nature of the strategy (space-dilating, space-conserving, or space-contracting).

The nearest-neighbor [$\alpha_i = \alpha_j = +0.5$, $\beta = 0$, $\gamma = -0.5$], group-average [$\alpha_i = n_i/n_k$, $\alpha_j = n_j/n_k$, $\beta = \gamma = 0$ where n_z is the number of items in the zth cluster], and flexible [$\alpha_i + \alpha_j + \beta = 1$, $\alpha_i = \alpha_j$, $\beta < 1$, $\gamma = 0$] sorting strategies were used to construct several different cluster interpretations. The nearest-neighbor strategy is intensely space-contracting, tending to cause large clusters to be formed. The group-average is space-conserving, incorporating little artificial sharpening of the cluster boundaries. The flexible strategy ranges from space-contracting to space-dilating as the value of β become negative. A commonly used β value for this strategy is -0.25 (Lance and Williams, 1977). This value proved overly space-dilating and a value of -0.05 was found to better separate groups of stations at high similarity levels.

Cluster Analysis and the Delineation of Species Groups

A clustering technique was also used to delineate species groups. The species themselves became the clustered entities while their abundances at given stations were the variables. This procedure is generally termed "inverse analysis," the station clustering being a "normal analysis." Williams and Lambert (1961) have developed some theoretical and practical aspects of this usage employing a correlation coefficient matrix. Field (1970) has also commented on the appropriateness of using various similarities in an inverse analysis and advocates the use of a presence/absence-based coefficient (as in McConnaughey, 1964) for the reason that consideration of differences in abundance may mask a real association between species with similar areal distribution (one being present in constantly lower numbers). However, it seems that differences in abundance are at least as important as the simple coincidence in the spatial distribution of species and for this reason the standard Czekanowski coefficient which does recognize abundance differences was used.

The problems associated with abundance effects in a species groups analysis are also mitigated by a logarithmic transformation. Thus, the only species grouping effort that will be used in this report is based on the Czekanowski coefficient calculated for natural logarithm of the variate values, clustered according to the group-average algorithm.

Principal Components Analysis and the Delineation of Station Groups

The technique of principal components analysis has found many applications in ecological work. Development of the technique may be traced to Pearson (1901) and Hotelling (1933). Excellent summaries of the extensive body of literature concerning the use of principal components analysis may be found in Gower (1967), Blackith and Reyment (1971), Morrison (1975), and Pielou (1977). The usual results of a principal components analysis are: (a) a set of projections of the entities onto a space of lower dimension than the original variate space; (b) a set of basis vectors for this space that are uncorrelated linear combinations of the original variates and used to explain the trends represented by the projections; and (c) a summary of the amount of variance accounted for by the projections onto the principal axes.

In this analysis only projections of the stations on the component axes were desired as it seemed that the 180 coefficients of the factors would be both too difficult to interpret and unnecessarily expensive to produce. Orloci (1966) has illustrated a "Q" technique for the method of principal components that bypasses the factor interpretation of the classical "R" technique but yields the desired projections.

The computation of solutions for both the R and Q techniques may be succinctly described. For the Q technique, given the matrix X, where the n columns represent the station counts for the m rows of species, the matrix A is formed by centering the rows of the X matrix. The projection vector y_i is then found as $y_i = \beta_i$, where β_i is the ith latent vector of the matrix $Q = A'A$ (A' denotes the transpose of the matrix A). The relation between R and Q techniques is that $y_i = A'\alpha_i$, where α_i is the ith latent vector of the matrix $R = AA'$. The proof of the duality of the two techniques depends on the equality of eigenvalues of the R and Q matrices. A formal development of this proof may be found in Gower (1966) and Orloci (1967). Finally, the total system variance equals the sum of the individual eigenvalues; hence, the proportion of variances associated with each principal component may be found as $\alpha_i / \sum_{i=1}^{n} \alpha_i$, where α_i is the eigenvalue associated with the ith eigenvector and n is the rank of the matrix A.

The Q technique may make much smaller demands of the computer than the R technique since it necessitates the extraction of the latent vectors of the smaller matrix when the number of variates (species) exceeds the number of cases (station). A salient point, however, is that its use bypasses the generation of the vector α, which is normally the subject of study in a classical principal components analysis. Since in the present study the number of variables far exceeds the number of cases, use of the Q technique was highly favored and was chosen for use over the R technique.

Principal component results from both the variance-covariance and the correlation matrices were obtained. To accomplish this the matrix X was alternately centered by row and then centered and standardized by row as follows (see Orloci, 1966):

Variance-covariance
$$a_{ij} = \frac{x_{ij} - \bar{x}_i}{\sqrt{n-1}}$$

Correlation
$$a_{ij} = \frac{x_{ij} - \bar{x}_i}{\overline{\sum_{k=1}^{n} (x_{ik} - \bar{x}_i)}}$$

where x_{ij} is the number of individuals of the ith species found at the jth station, $\bar{x}_i$ is the mean value for the ith species taken over all stations (the row mean), and n is the number of observations (stations). By this method, two different analyses are performed yielding station projections exactly equal to those produced by the principal components analysis of the covariance and correlation matrices respectively. Mathematical operations involved in this technique are summarized in Appendix IV.

Principal Coordinate Analysis and the Delineation of Station Groups

The method of principal coordinates analysis was developed by Gower (1966) and is so similar to principal components analysis that the two have been lumped along with several other techniques into the general category of "inertial methods" by Chardy, Glemarec, and Laurec (1976). The results of a principal coordinates analysis are again projections of stations onto principal axes, but the model on which these projections are based differs from that of principal components analysis. Original interpoint distances are defined by an appropriate similarity or distance measure (the Czekanowski or the Canberra metric, for example). S is an n×n similarity matrix similar to that calculated at the initial stage of a cluster analysis. Coordinates of the point Q_i (the ith point or station) constitute the ith component of each of the latent vectors of the S matrix.

A principal components analysis, using as variables the latent vectors of this Q matrix, yields a centered representation of the original points in a multidimensional space. The procedure may then be described as: (a) a co-ordination of the association matrix and (b) the subsequent principal components analysis of these coordinates to produce a least squares projection onto as many axes as are desired. As in principal components analysis, the proportional variance associated with each individual component is based on the eigenvalue corresponding to that component (% variance = $\alpha_i / \sum_{i=1}^{n} \alpha_i$).

The process described above requires the extraction of latent vectors of two matrices whose dimensions are determined by the number of stations under analysis (i.e., S is n×n). The method requires extraction of the eigenvectors of only one matrix if the original association matrix (S) is first transformed according to the formula:

$$q_{ij} = s_{ij} - \bar{s}_i - \bar{s}_j + \bar{s} ,$$

where q_{ij} and s_{ij} are the corresponding ith row, jth column elements of matrices Q and S respectively. The projection vector y_i may again be found as $y_i = \beta_i$, where β_i is the ith latent vector of the Q matrix scaled such that $\beta_i'\beta_i = \gamma_i$, where γ_i is the ith latent root. Gower (1967) has shown that this method will be valid (i.e., result in a real configuration of points) for a wide variety of association matrices. In the current study, both the Czekanowski and Canberra metric coefficients were used as distance functions in the principal coordinates analysis. The mathematical operations used in this technique are also summarized in Appendix IV.

Differences between Principal Coordinates and Principal Components Analysis

While the formal results of the principal coordinates analysis and the principal components analysis (based on a Q technique) are similar (i.e., a projection of stations onto a low dimensional space--typically, that defined by the first three component axes), the underlying model is different. An understanding of these differences is essential to the complete utilization of these methods.

Principal components analyses are based on variance covariance or correlation matrices. The correlation measure may be thought of as a standardization of the raw data to terms of standard deviations and results in a mitigation of the effects of large departures of the variates from their respective means.

Principal coordinates analysis is based on an association matrix for which the definition of distance is rooted in ecological considerations. These distances ultimately determine the relative positions of stations and should be based on a desired weighting for the variables. The significant implication for this work is that the principal coordinates analysis based on the Canberra metric coefficient will be less influenced by dominant species than will that of the Czekanowski coefficient.

Finally, if an R technique is used to arrive at the principal components projection, the factor interpretation can be an integral part of the principal components analysis. Analysis of component coefficients affords us a direct knowledge of the roles of all variables in producing the projections. Such capabilities are not a part of the principal coordinates analysis.

Measurement of Diversity

The Shannon and Brillouin measures of diversity and the Simpson index of dominance were calculated from the data on numbers of individuals per square meter. Their formulas, according to Pielou (1977) are as follows:

$$\text{Brillouin index} \qquad H = \frac{1}{N} \log \frac{N!}{N_1!N_2!\ldots N_s!} ,$$

where s equals the number of species, and N_j equals the number of individuals of the jth species and $N = \sum_{j=1}^{s} N_j$.

$$\text{Shannon index} \qquad H' = c \sum_j p_j \log p_j$$

where c is a positive constant, p_j is the proportion of individuals from the population that are of the jth species ($p_j = N_j/N$). In addition, species richness has been calculated after the development of Margalef (1968) as:

$$D = (s-1)/\ln N ,$$

where s equals the number of species and N the number of individuals. A discussion of the theory behind these measures and the attendant implications of their use may also be found in Pielou (1977). General difficulties involved in using diversity indices are related to inequalities in both the numbers of species found and the number of individuals found in the different sampled sites. An increase in either tends to increase the value of the index and, though the increase may be small, the end result is that it is usually difficult to draw comparisons in diversity between sampled areas. As the number of species and the number of individuals found in the areas to be compared become closer, comparisons become more meaningful. Unfortunately, such equality or near equality is rarely encountered in surveys of the marine benthos. Sanders (1968) has formulated a method to circumvent the above mentioned difficulties but his approach was beyond the scope of this study.

The Shannon index is used to estimate diversity of a large population from a sample and has an associated sampling error. Some use of this index will be made in a later section of the thesis, although no attempt has been made to estimate the sampling variance of this estimate. The Brillouin index is used to measure the diversity of a population or collection that is assessed in entirety and is therefore free of sampling error. The Simpson index is used here as a dominance measure, although it may be easily transformed to a diversity measure with characteristics inferior to the other two diversity indices mentioned above (Pielou, 1977).

The Simpson dominance and Brillouin diversity indices can be used to examine both the diversity of the grab contents and the effects of dominance on the results of various cluster alternatives. The collection of organisms to be assessed must then differ. In studies of the entire community, the entire array of organisms captured by the grab should be considered. When examining the effects of dominance on cluster or ordination analysis, the appropriate set is composed only of those organisms used in the analysis.

RESULTS AND DISCUSSION

STATION CLUSTERING

All clustering programs were written by University of Alaska personnel or adapted from Anderberg (1973). The dendrograms resulting from the cluster analyses are shown in Figures 2 through 5. The most useful results were obtained using the group average and flexible ($\beta = -0.05$) sorting strategies; therefore, only dendrograms originating from these strategies have been included. Clusters were initially determined by drawing a line across the dendrogram at approximately the .30 similarity level; groupings formed to this point were then evaluated as clusters. Subsequent cluster redefinitions were achieved by examining both the next larger and next smaller clusters corresponding to the next lower and higher similarity levels indicated on the dendrogram. The station groupings selected by this reexamination are shown in Figures 6 through 9.

Table 3 lists stations that have been designated core groups on the basis of their consistent conjoint appearance in clusters. It is apparent

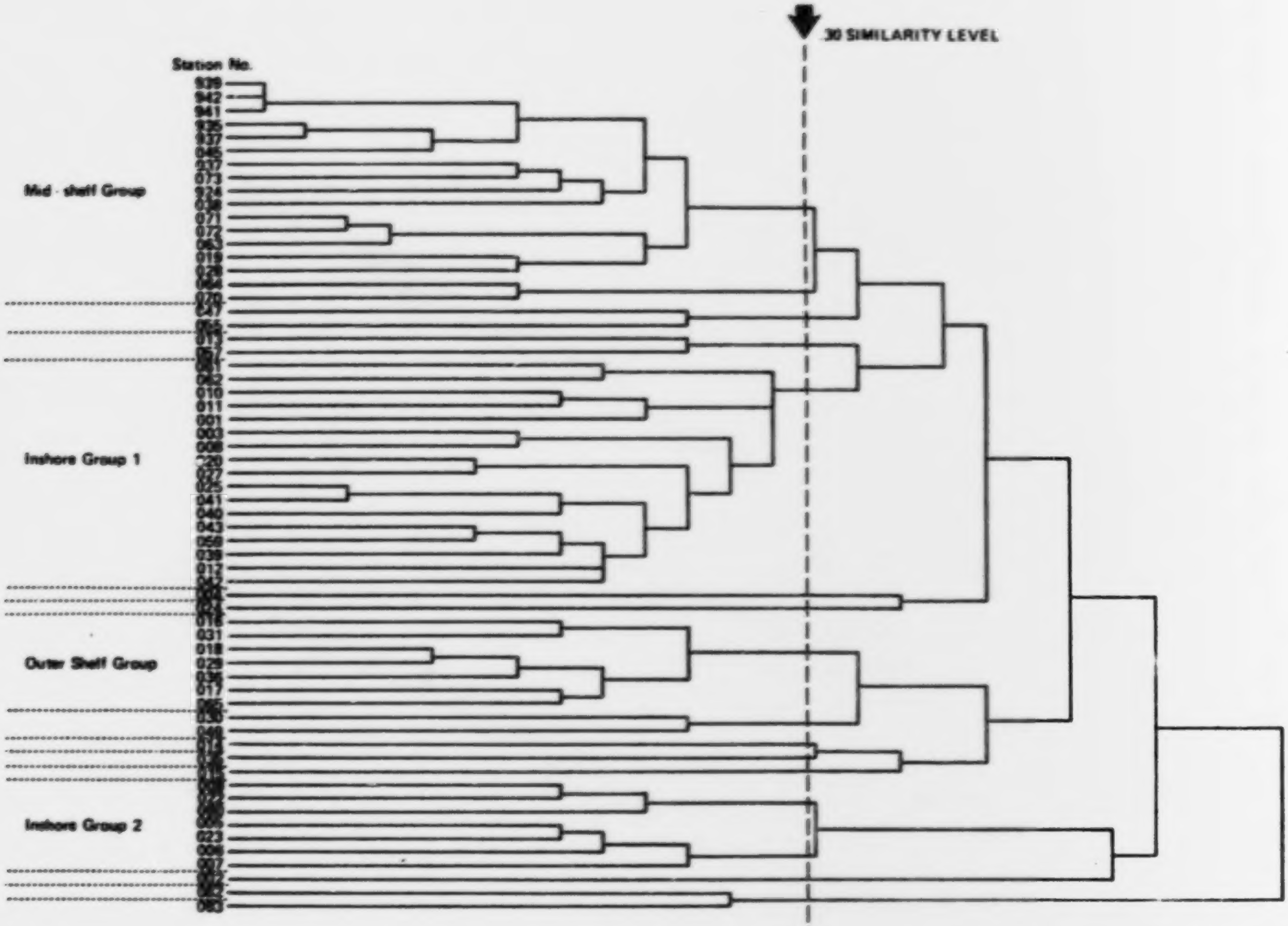

.30 SIMILARITY LEVEL
Station No.
939
942
941
937
045
037
073
024
071
072
063
019
010
011
001
003
008
027
025
041
040
043
050
017
016
031
018
029
017
023
006
083
Mid - shelf Group
Inshore Group 1
Outer Shelf Group
Inshore Group 2

Figure 2. Dendrogram resulting from the clustering of stations using the Czekanowski distance measure and a flexible sorting strategy.

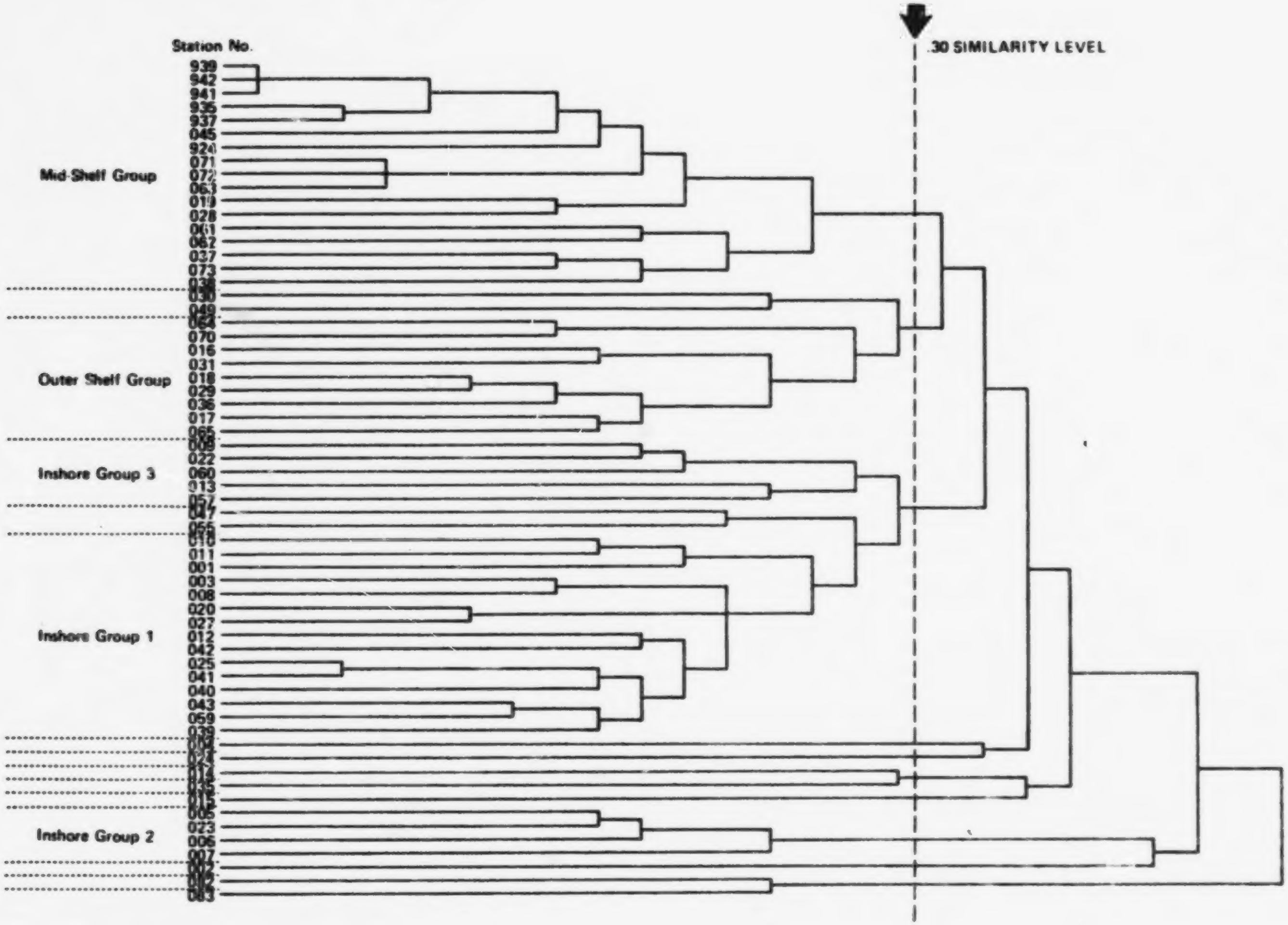


Figure 3. Dendrogram resulting from the clustering of stations using the Czekanowski distance measure and a group-average sorting strategy.

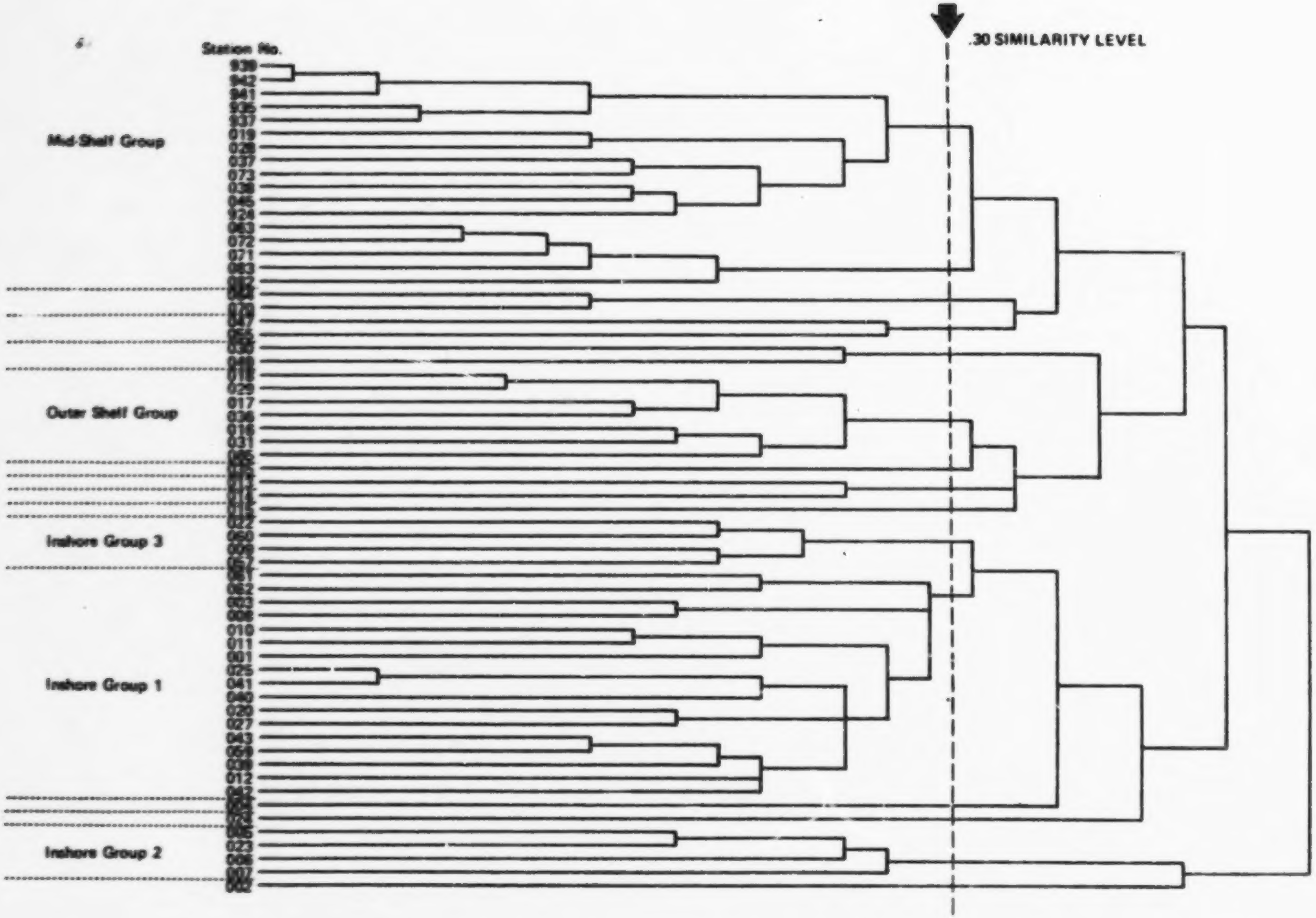


Figure 4. Dendrogram resulting from the clustering of stations using the Canberra-metric distance measure and a flexible sorting strategy.

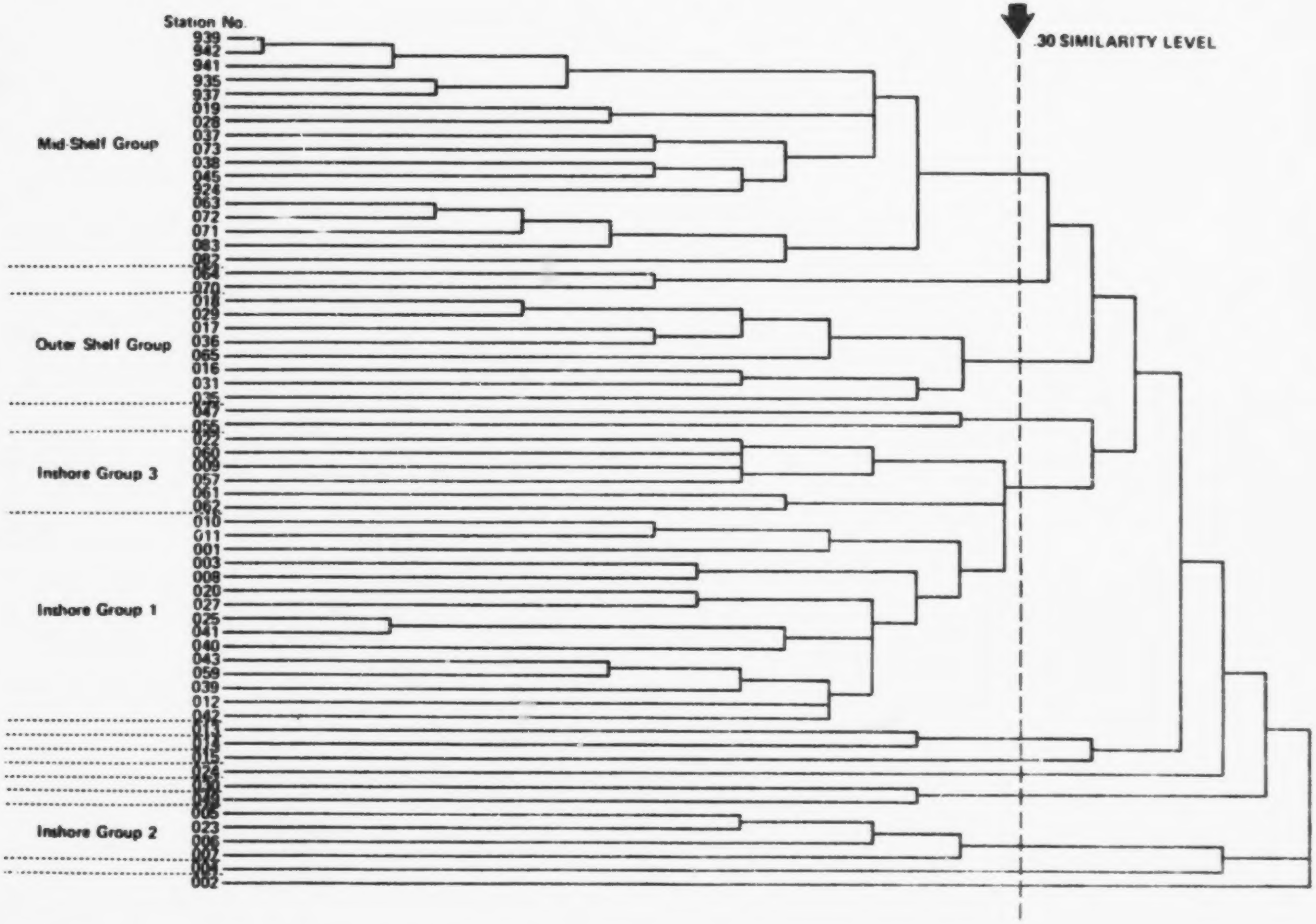


Figure 5. Dendrogram resulting from the clustering of stations using the Canberra-metric distance measure and a group-average sorting strategy.

BEST DOCUMENT AVAILABLE

326

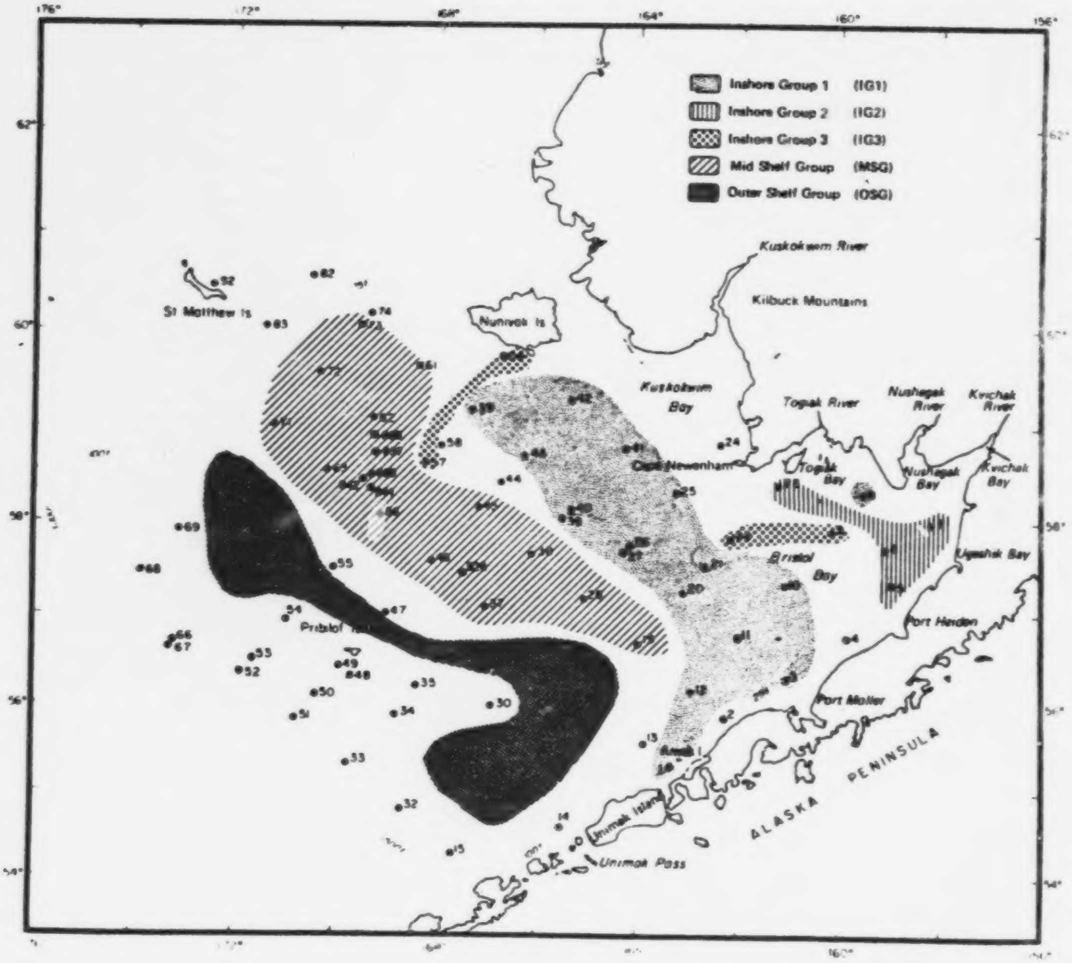

Inshore Group 1 (IG1)
Inshore Group 2 (IG2)
Inshore Group 3 (IG3)
Mid Shelf Group (MSG)
Outer Shelf Group (OSG)
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Togiak Bay
Nushagak River
Nushagak Bay
Kvichak River
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Isl.
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 6. Station groups indicated by the results of a cluster analysis based on the Czekanowski dissimilarity measure and using a group average sorting strategy.

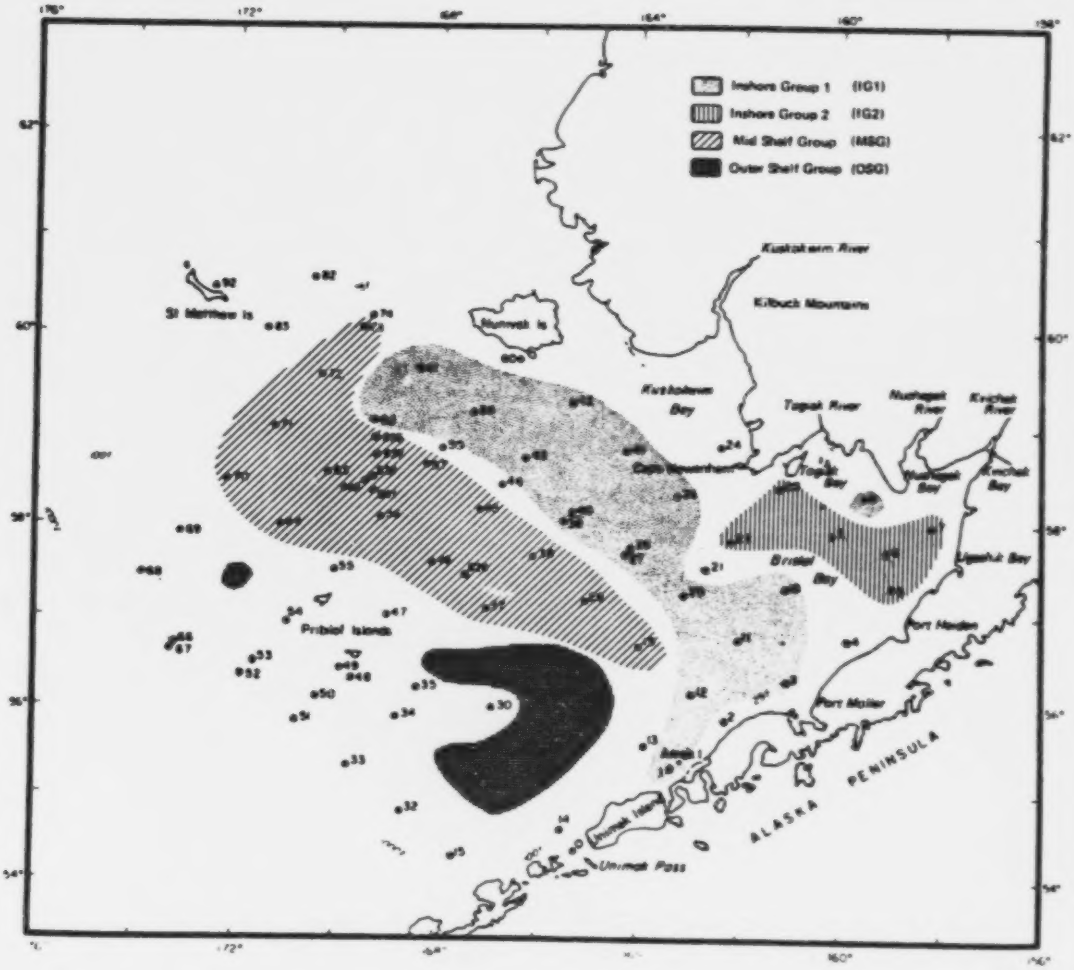

Inshore Group 1 (IG1)
Inshore Group 2 (IG2)
Mid Shelf Group (MSG)
Outer Shelf Group (OSG)
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Togiak Bay
Nushagak River
Nushagak Bay
Kvichak River
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Unimak Island
Unimak Pass
ALASKA PENINSULA
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 7. Station groups indicated by the results of a cluster analysis based on the Czekanowski dissimilarity measure and using a flexible-sorting strategy ($\beta = -0.05$).

BEST DOCUMENT AVAILABLE

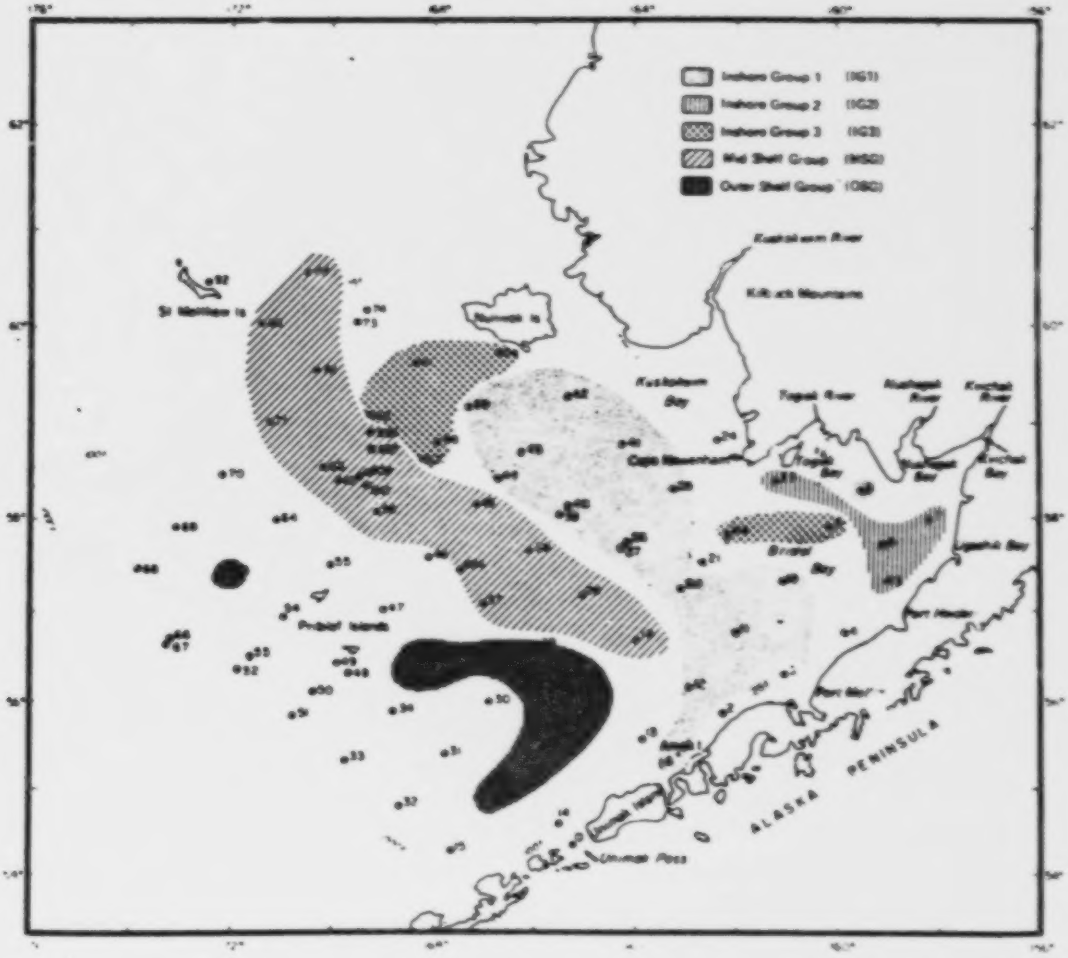

Inshore Group 1 (IG1)
Inshore Group 2 (IG2)
Inshore Group 3 (IG3)
Mid Shelf Group (MSG)
Outer Shelf Group (OSG)
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Bristol Bay
Pribilof Islands
Unimak Pass
ALASKA PENINSULA

Figure 8. Station groups indicated by a cluster analysis based on the Canberra-metric distance measure and using a group-average sorting strategy.

BEST DOCUMENT AVAILABLE

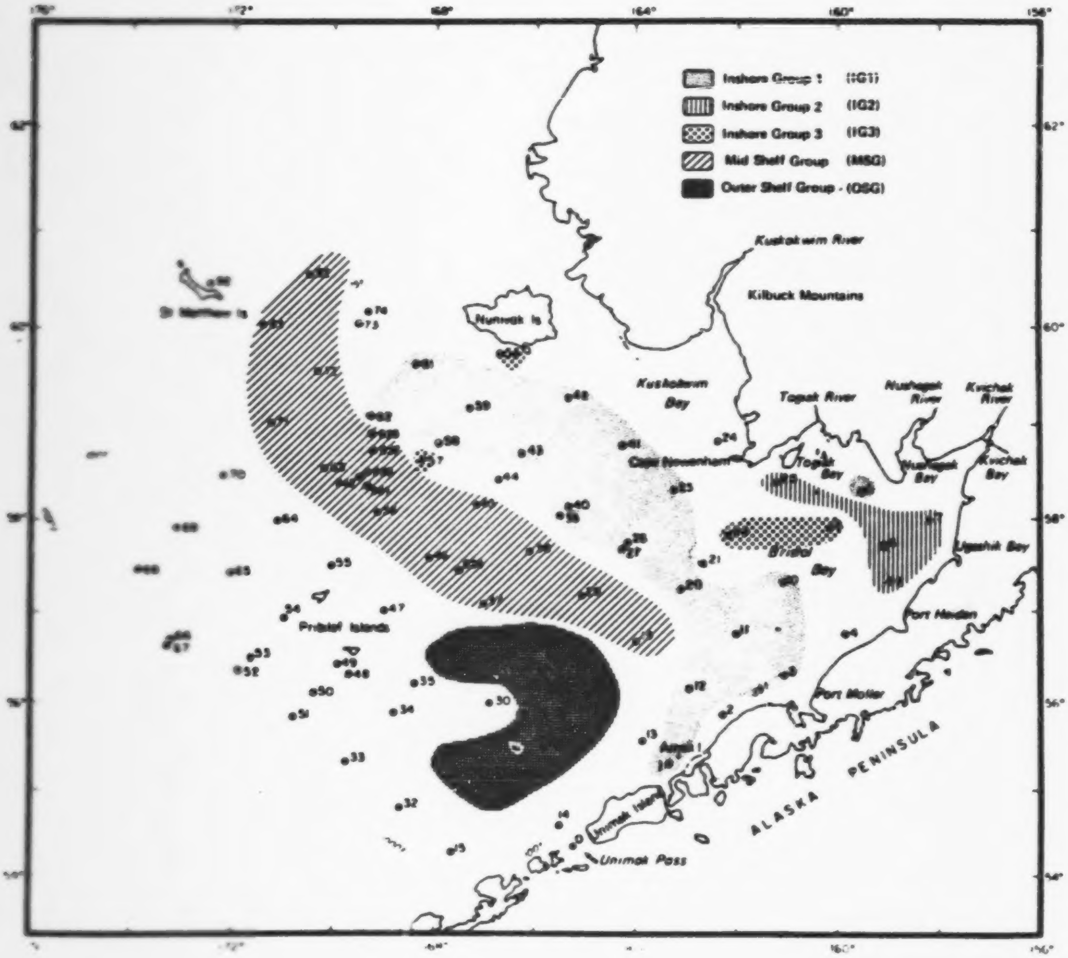

Inshore Group 1 (IG1)
Inshore Group 2 (IG2)
Inshore Group 3 (IG3)
Mid Shelf Group (MSG)
Outer Shelf Group - (OSG)
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Unimak Island
Unimak Pass
ALASKA PENINSULA
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 9. Station groups indicated by a cluster analysis based on the Canberra-metric distance measure and using a flexible sorting stretegy (β = -0.05).

Table 3. Bering Sea infaunal study: station groups identified by cluster analysis at .30 similarity level.

Stations	Group	Clustering Strategy
1,3,8,10,11,12,20,25,27 39,40,41,42,43,59	IG1	Czekanowski--group average
As above with 61 and 62		Czekanowski--flexible (β = -0.05)
As above with 61 and 62		Canberra metric--flexible (β = -0.05)
As above without 61 and 62		Canberra metric--group average
5,6,7,23	IG2	Czekanowski--group average
5,6,7,9,22,23,60		Czekanowski--flexible (β = -0.05)
5,6,7,23		Canberra metric--flexible (β = -0.05)
5,6,7,23		Canberra metric--group average
9,13,22,57,60	IG3	Czekanowski--group average
nonexistent-merges with IG2		Czekanowski--flexible (β = -0.05)
9,22,57,60		Canberra metric--flexible (β = -0.05)
9,22,57,60,61,62		Canberra metric--group average
19,28,37,38,45,63,71,72,73, 924,935,937,939,941	MSG	Czekanowski-group average
As above with 64 and 70		Czekanowski--flexible (β = -0.05)
As above with 82 and 83		Canberra metric--flexible (β = -0.05)
As above with 82 and 83		Canberra metric--group average
16,17,18,29,31,36,64,65,70	OSG	Czekanowski--group average
16,17,18,29,31,36,65		Czekanowski--flexible (β = -0.05)
16,17,18,29,31,36,65		Canberra metric--flexible (β = -0.05)
16,17,18,29,31,35,36,65		Canberra metric--group average
2,4,15,19,24,35; 30,49; 47,55; 82,83	Singles and small groups	Czekanowski--group average
2,4,15,24; 47,55; 82,83		Czekanowski--flexible (β = -0.05)
2,4,24; 30,49; 64,70; 47,55		Canberra metric--flexible (β = -0.05)
2,4,15,24; 30,49; 13,14,47,55		Canberra metric--group average

from Figures 6 through 9 and Table 3 that: (1) certain stations repeatedly group together by different analyses and (2) the composition of most clusters, while generally verified by several procedures, is inherently variable. The differences between the interpretations is at least as interesting as the similarities, and stem from the basic options (i.e., similarity measure and sorting strategy) discussed in the preceding section. This topic will be dealt with after the results have been described.

The core station groups may be characterized as follows (Figs. 6 through 9):

IG1 -- (Inshore Group 1) This large group is comprised of stations which lie, for the most part, under waters of less than 50 m depth, with several stations (10, 11, 12, and 20) lying in slightly deeper water (maximum is 83 m). Most members lie at least 60 km from land, with Stations 1, 3, and 8 anomalous in that they lie just off (∿20 km) the Alaska Peninsula (Stations 1 and 3) or the Bristol Bay coast (Station 8).

IG2 -- (Inshore Group 2) This group is a consistent four station group found along the coast in Bristol Bay. Under the flexible strategy using Czekanowski's coefficient, it merges with IG3; otherwise it stands alone.

IG3 -- (Inshore Group 3) This small group (Stations 9, 22, 60 and 57) includes Station 13 under the group average Czekanowski similarity classification and Station 61 and 62 under the group-average Canberra metric distance scheme. The only geographical continuity apparent in this cluster is that all stations are relatively close to the mainland but not, with the exception of Station 60 (lying just off Nunivak Island), directly offshore.

MSG -- (Mid-Shelf Group) This is a large group occupying a band roughly parallel to the 50 m bottom depth contour and extending seaward to stations in locations of about 80 m water depth. The southern end of the group, Station 19, is displaced slightly to the west and lies in water of 77 m depth. The northern boundary of the group is variable; it includes the northern most stations (82 and 83) under the Canberra metric classification, but usually terminates with the station string 71, 72, and 73.

OSG -- (Outer Shelf Group) This mid- to outer shelf group does not possess a consistent marked geographical pattern. All group members are outer shelf to shelf edge in position and, with the exception of Station 65, are found in the southwestern corner of the study area. Station 35 occasionally links with this cluster. Station 30, adjacent to OSG, invariably remains separate.

Outliers-- These are stations or pairs of stations that form no strong associations with the core groups. Under different analyses some of these stations may link with some of the groups outlined above, however Stations 2, 4, 15, and 24 are always single. The relations of individual outlying stations and pairs of outlying stations to other outliers and to the main station groups will be dealt with in a later section.

ORDINATION METHODS--THE CLASSIFICATION OF STATIONS

As mentioned earlier (see Methods), the models underlying the development of the various ordination techniques need to be understood to facilitate the interpretation of the results of these procedures. It should be emphasized that both principal coordinates and principal components analysis are sensitive to the presence of extreme values in the input data. In principal coordinates analysis, reduction of the effect of these extreme values may be accomplished by the use of a distance measure (e.g. the Canberra metric measure) that mitigates the effect of dominance. In principal coordinates analysis a similar function is performed by initially standardizing the variates (i.e., by finding the principal components of the correlation matrix rather than the covariance matrix).

The foregoing considerations carry several implications concerning the relation of ordination results to the outcome of a cluster analysis. The principal coordinates analysis based on a specific similarity or distance measure will obviously parallel the results of a cluster analysis based on the same measure. The outcome of a principal components analysis based on the correlation matrix will be similar to the results of both the cluster analysis and the principal coordinates analysis that are derived from a distance matrix for which the effect of dominance has been reduced.

The ordination methods used resulted in plots of station projections on principal axes; they are shown in Figures 10 through 21. Several plots are presented for each ordination procedure, the difference between plots of any given ordination output being that individual stations or groups of stations have been removed to clarify specific relationships. Also, the station group memberships suggested by cluster analysis results have been

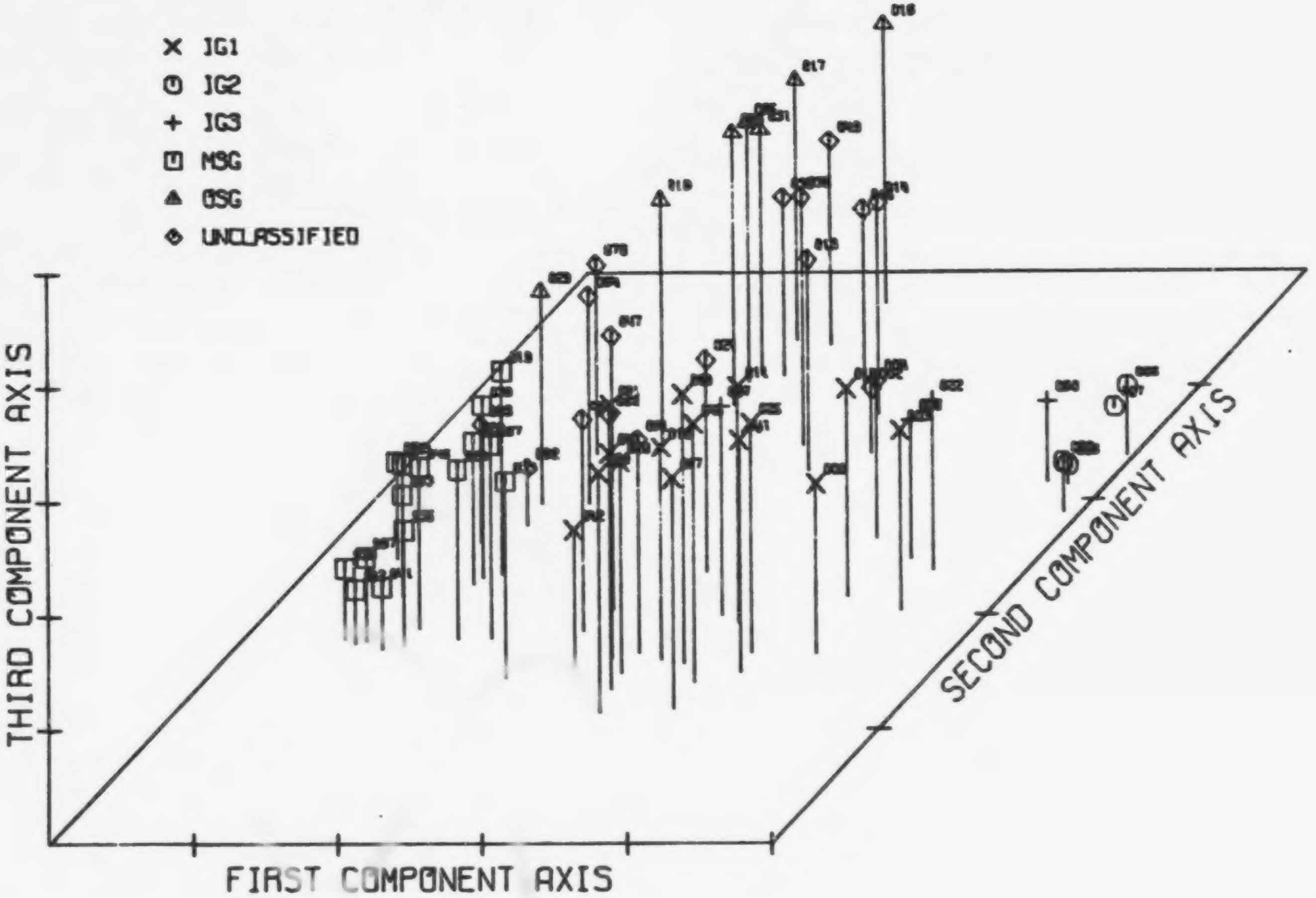


Figure 10. Projections of all Bering Sea infaunal stations onto the first three axes derived from a principal coordinates analysis based on Czekanowski dissimilarity measure.

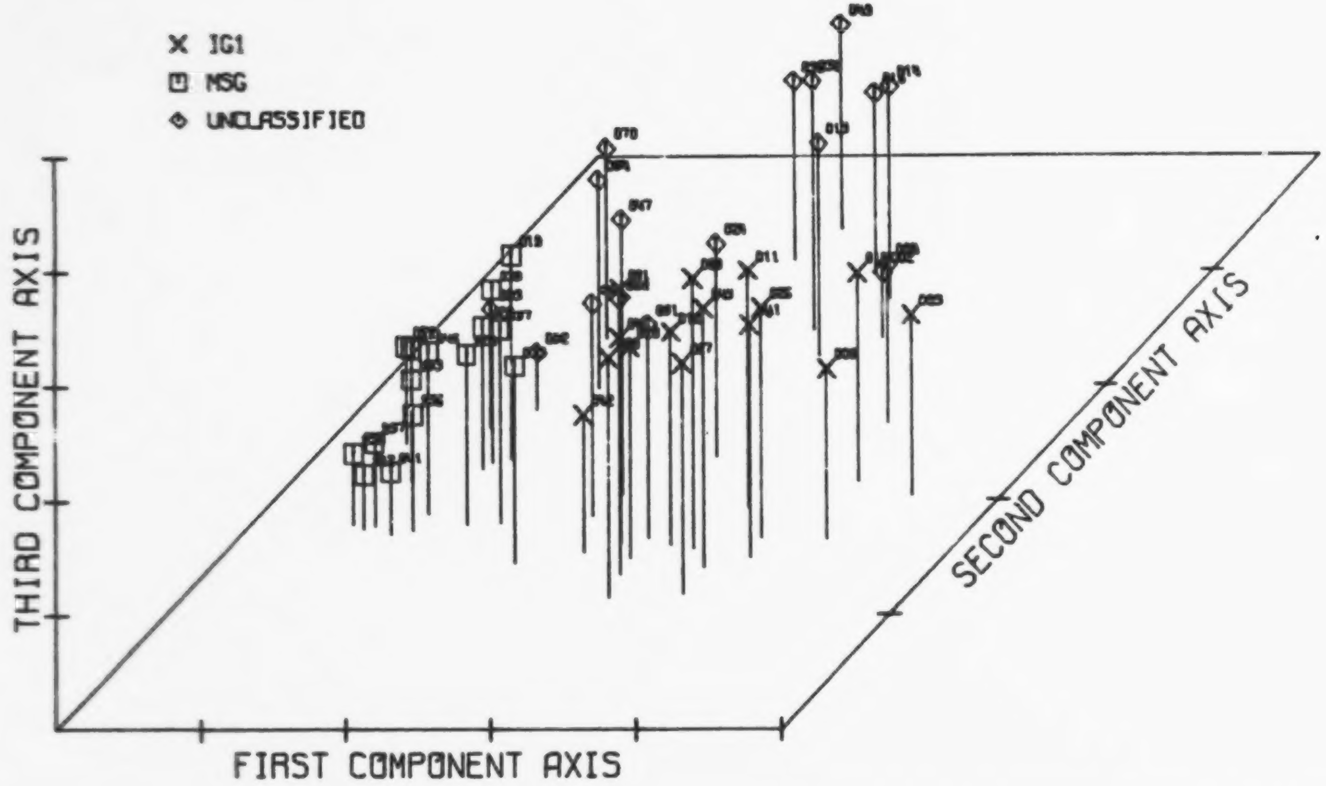


Figure 11. Projections of stations onto principal axes (principal coordinates analysis, Czekanowski distance) as in Figure 10, but with groups IG2, IG3, and OSG omitted.

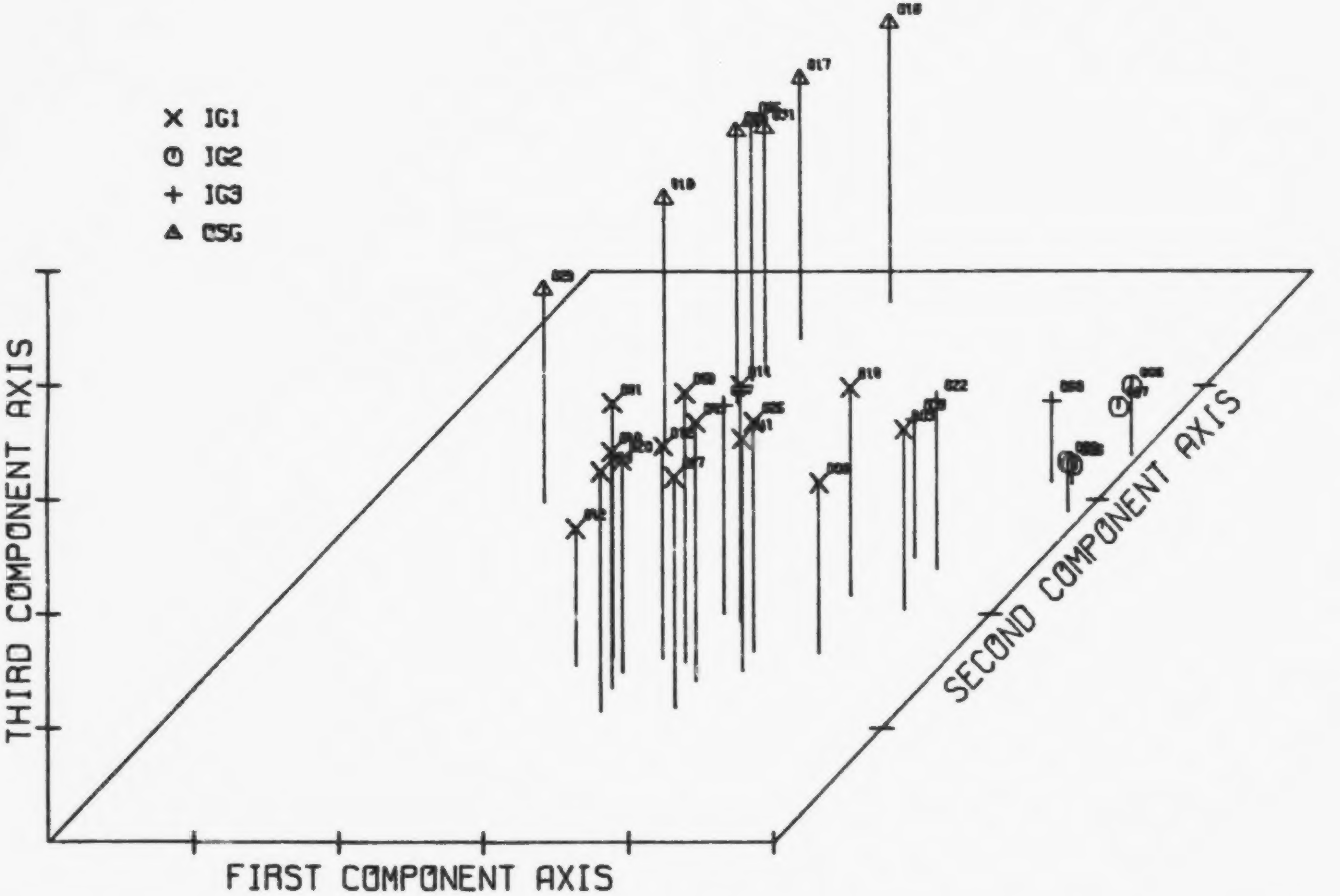


Figure 12. Projections of stations onto principal axes (principal coordinates analysis, Czekanowski distance) as in Figure 10, but with MSG and unclassified stations omitted.

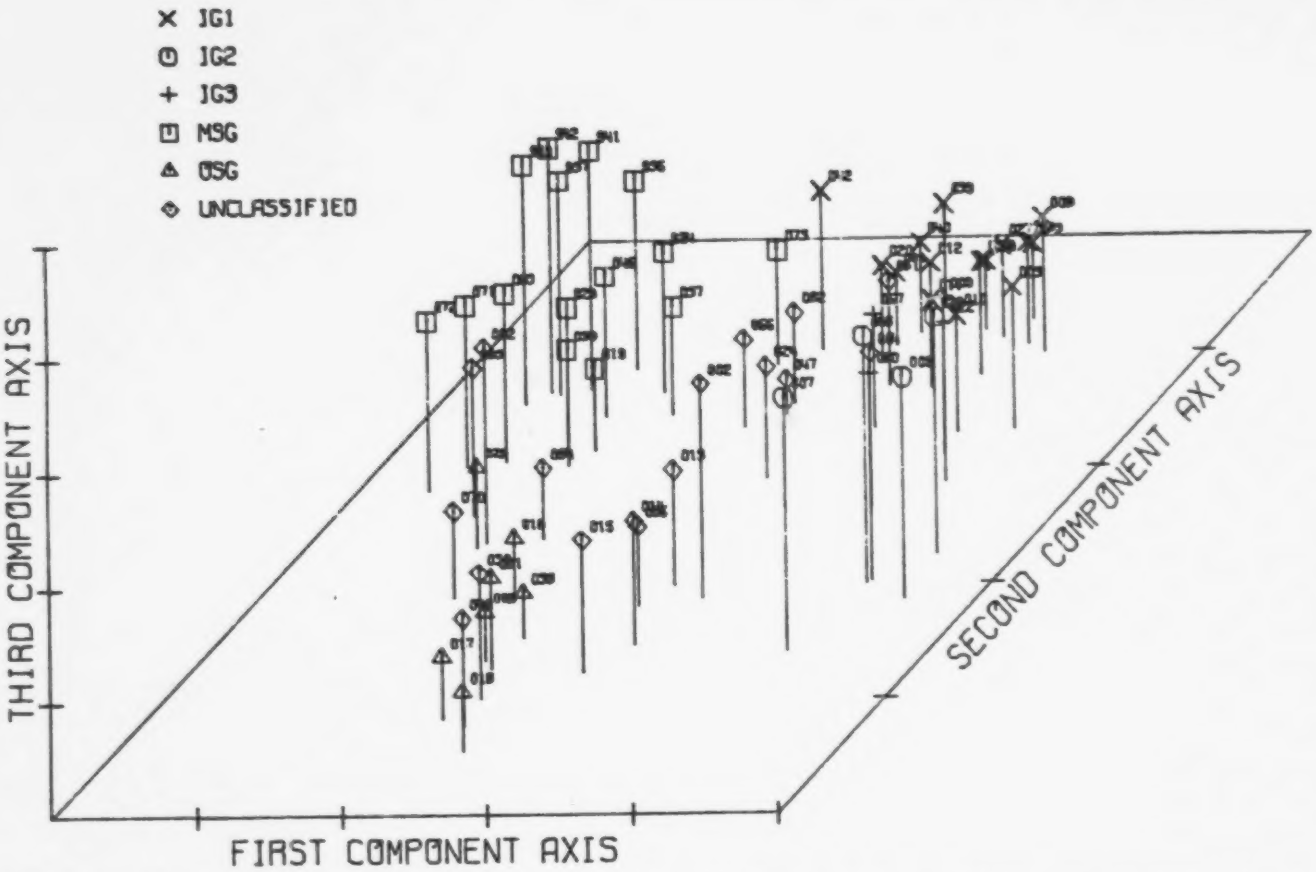


Figure 13. Projections of all Bering Sea infaunal stations onto principal axes defined by a principal coordinates analysis based on the Canberra-metric dissimilarity measure.

BEST DOCUMENT AVAILABLE

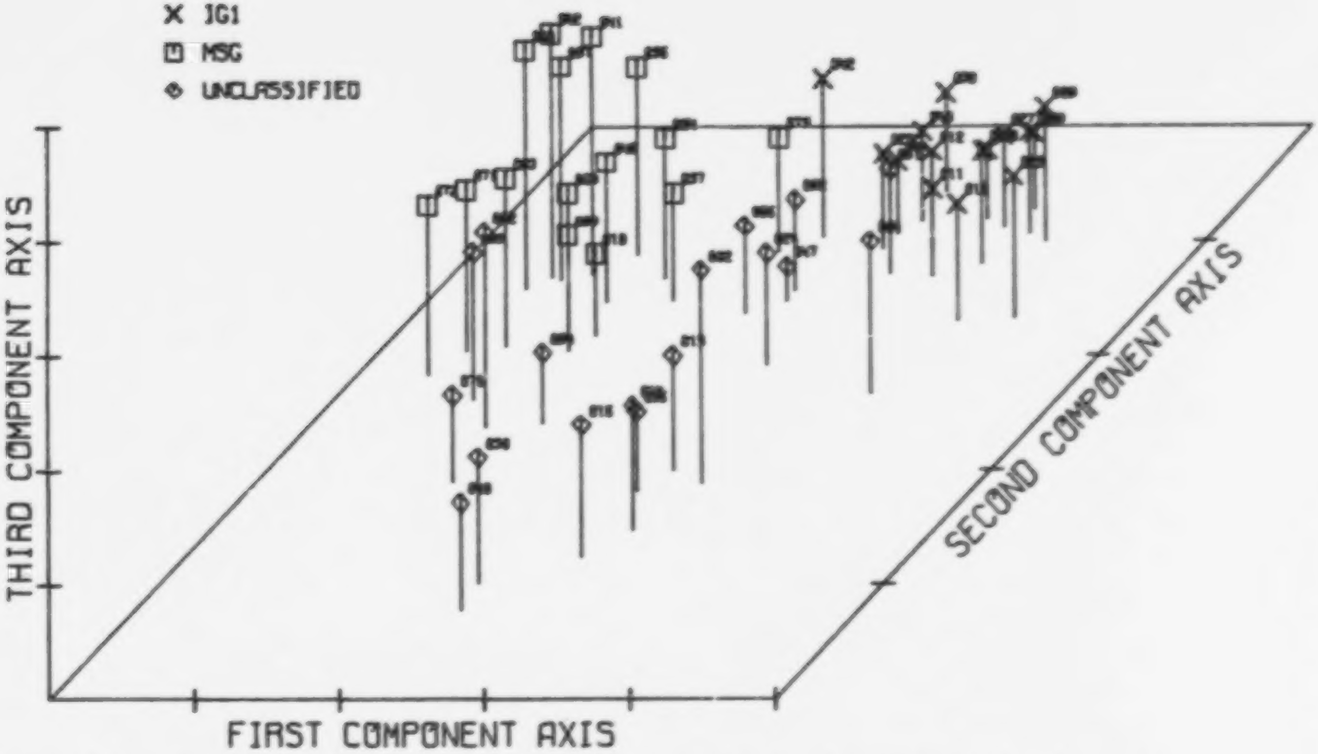


Figure 14. Projections of stations onto principal axes (principal coordinate analysis, Canberra-metric distance) as in Figure 13, but with groups IG2, IG3 and OSG removed.

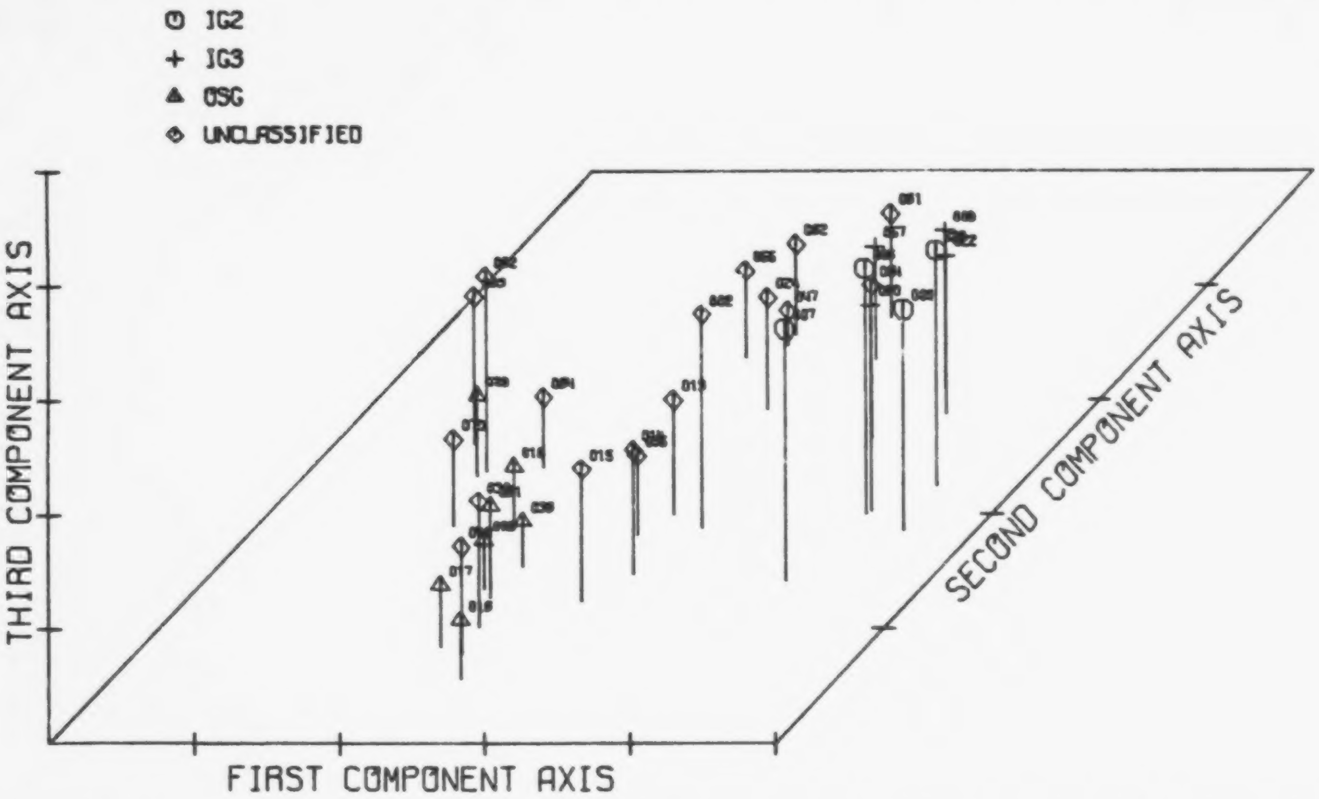


Figure 15. Projections of stations onto principal axes (principal coordinates analysis, Canberra metric distance) as in Figure 13, but with groups IG1 and MSG removed.

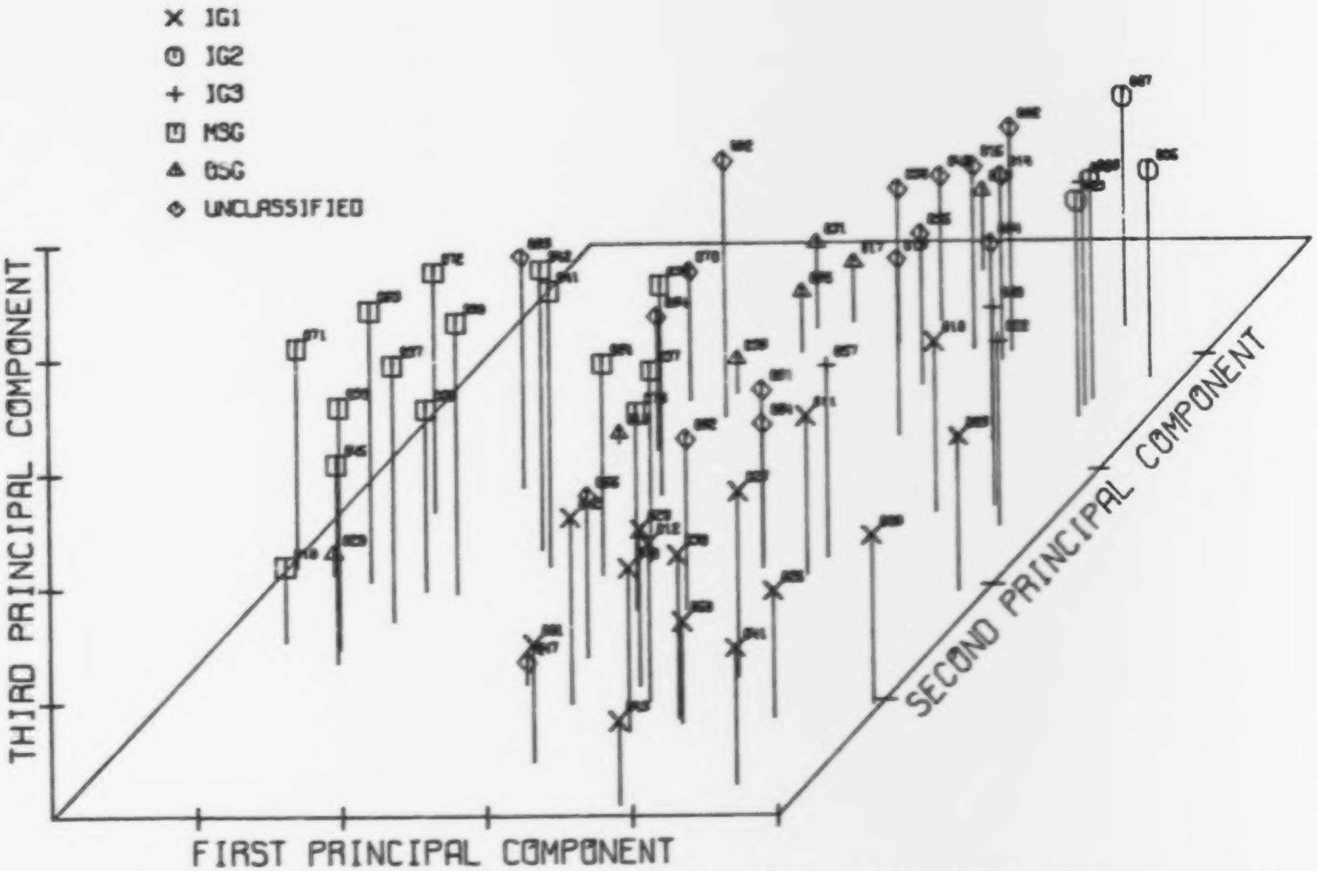


Figure 16. Projections of all Bering Sea infaunal stations onto the first three axes defined by a covariance-based principal components analysis.

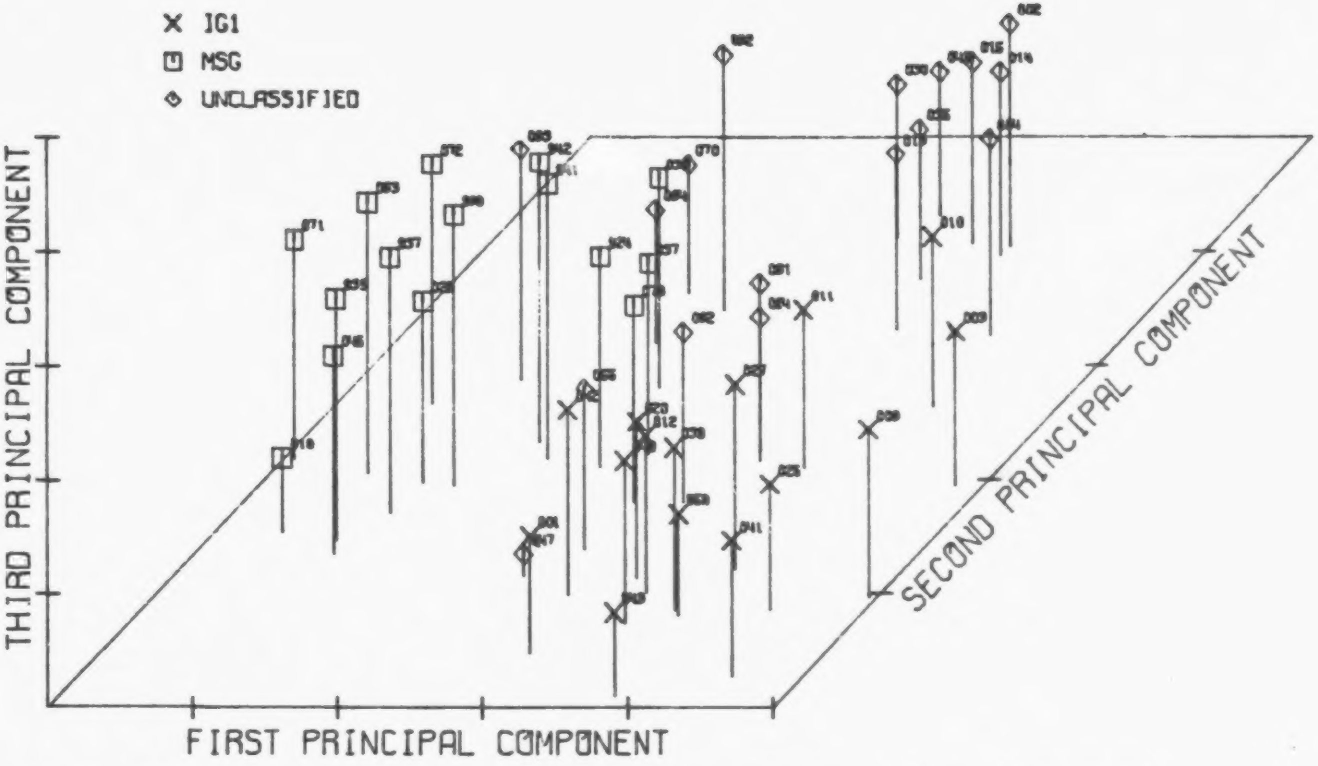


Figure 17. Projections of stations onto principal axes (principal components analysis, covariance matrix) as in Figure 16, but with groups IG2, IG3, and OSG removed.

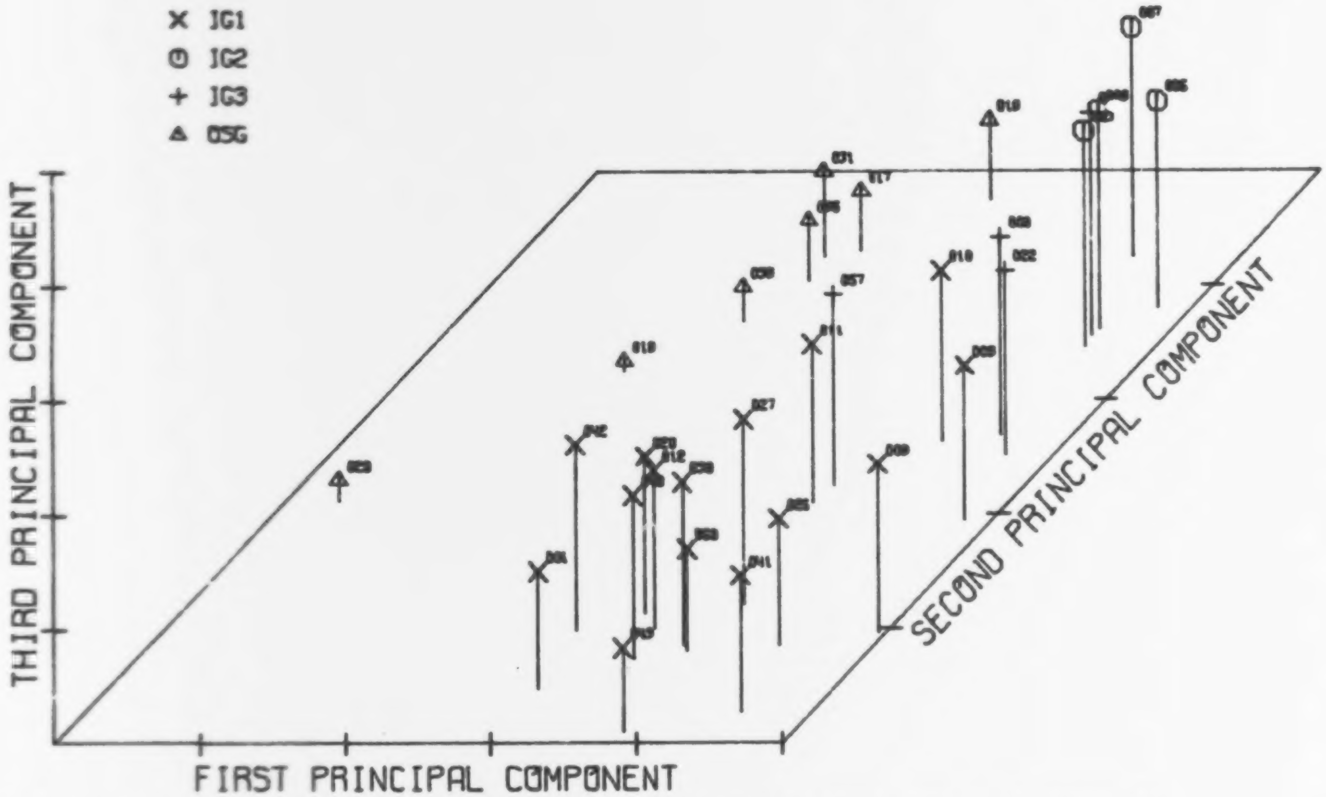


Figure 18. Projections of stations onto principal axes (principal components analysis, covariance matrix) as in Figure 16, but with MSG and unclassified stations removed.

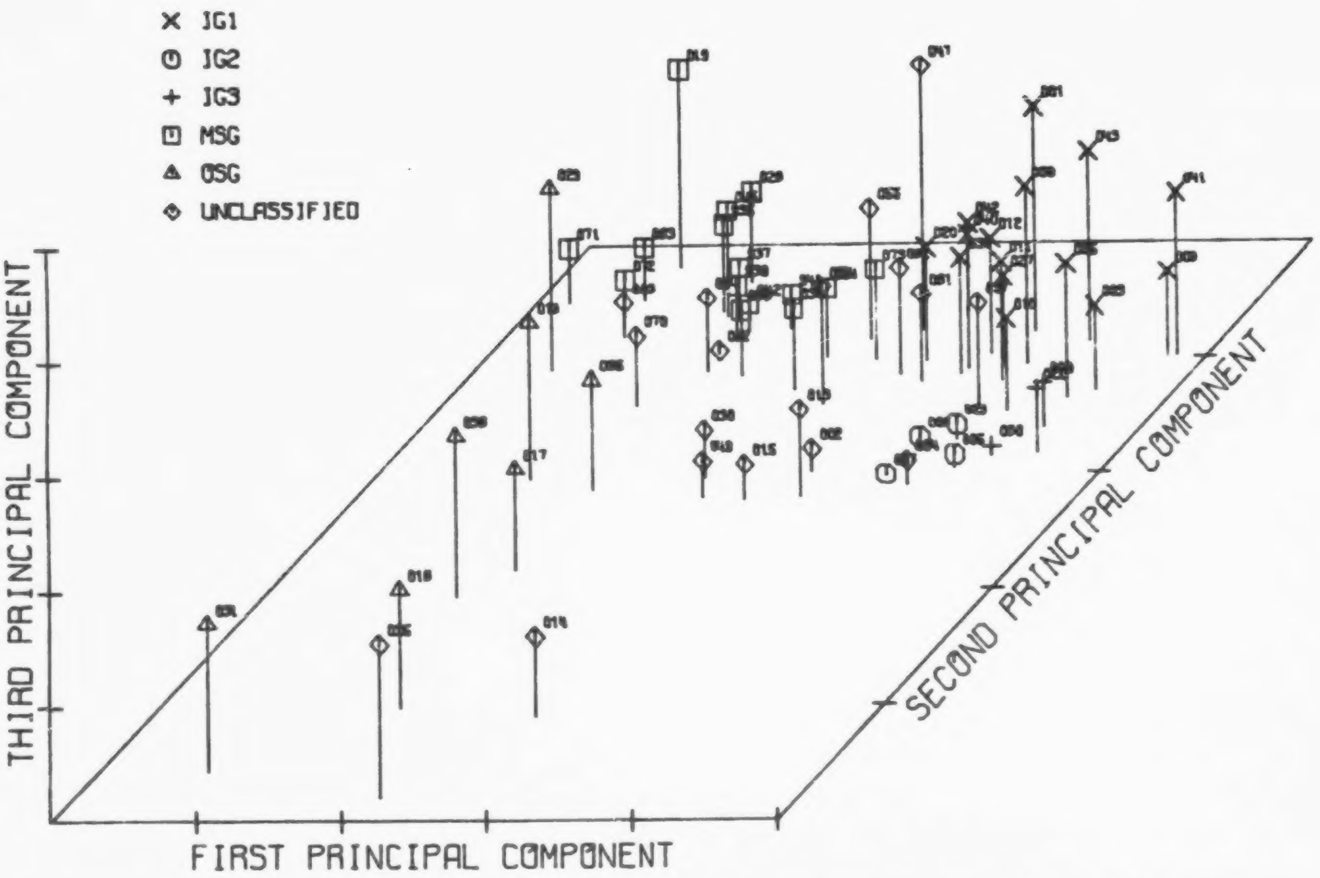


Figure 19. Projections of all Bering Sea infaunal stations onto the first three principal axes defined by a correlation-based principal components analysis.

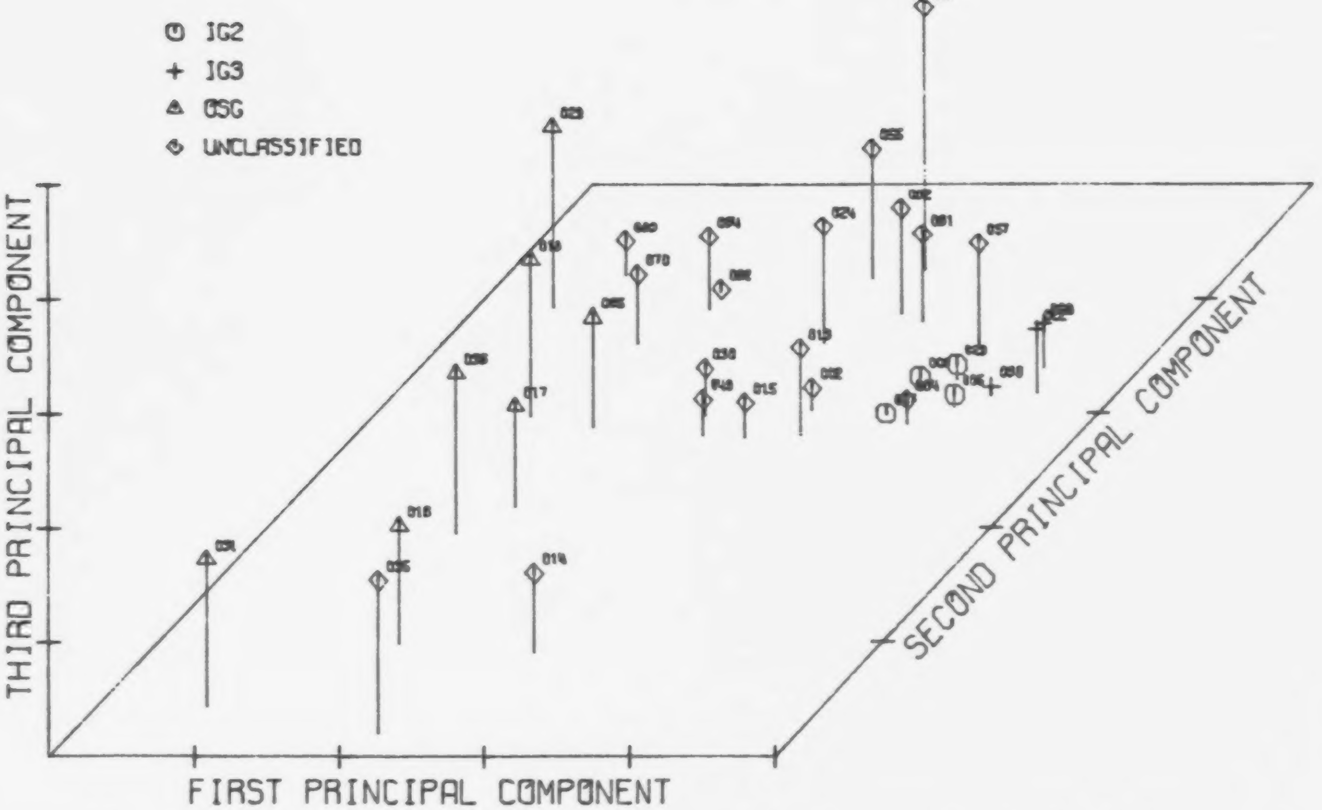


Figure 20. Projections of stations onto principal axes (principal components analysis, correlation matrix) as in Figure 19, but with groups IG1 and MSG removed.

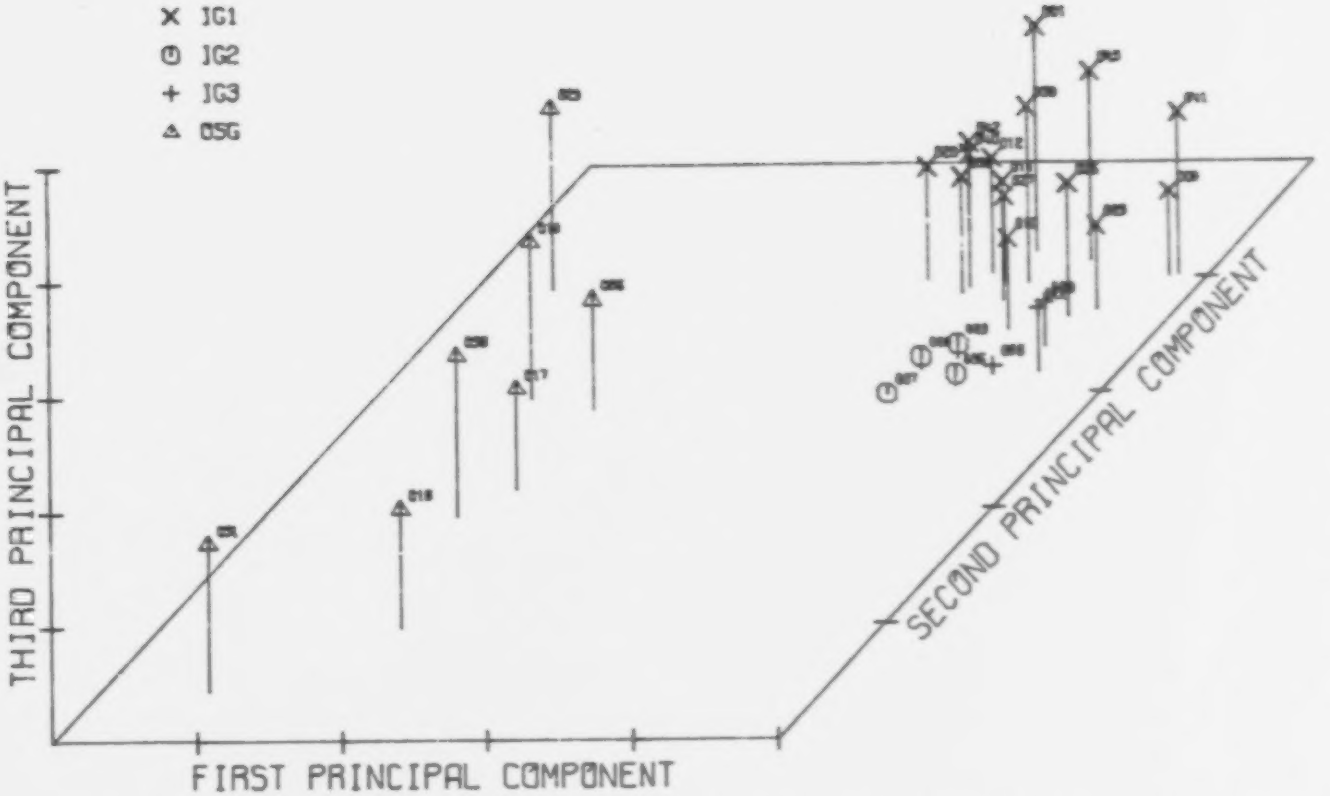


Figure 21. Projections of stations onto principal axes (principal components analysis, correlation matrix) as in Figure 19, but with unclassified stations and MSG removed.

indicated to give some idea of the agreement between these techniques. An interpretation of these figures follows.

PRINCIPAL COORDINATES ANALYSIS

Analysis Based on the Czekanowski Coefficient

A plot of the projections of all stations, produced by use of this coefficient, is shown in Figure 10. Immediately apparent is the good separation between MSG, IG1, IG2, and IG3 and the relatively poor resolution of OSG. The relationship of outliers to the main groups is more easily seen in Figure 11, which has had the stations of IG2, IG3, and OSG removed. It is apparent that Stations 61 and 62 are among the stations of IG1, and 82 and 83 with MSG. It also seems that Station 8 might be displaced towards IG3. Figure 12 shows the close association between IG1 and IG3. The proportions of variance accounted for by the first three axes are 7.8%, 6.1%, and 3.2% for components one, two, and three, respectively.

Analysis Based on the Canberra Metric Measure

Figure 13 (all stations included) shows an excellent discrimination between MSG and IG1. This difference is most evident on the first principal axis and probably results in the corresponding scatter in the remaining groups on that axis. The outlier relationships to IG1 and MSG indicated by the Czekanowski-based analysis are little changed by the Canberra-metric-based analysis, as illustrated by Figure 14 (IG2, IG3, and OSG removed). Stations 82 and 83 are closely tied to MSG although their relative positions are reversed when compared to those derived from analysis based on the Czekanowski coefficient. Station 61 falls out near IG1, although Stations 57 and 4 are also found in the general area. Figure 15 illustrates the sort of confusion that outliers bring into this type of study. It is very difficult to draw station group boundaries between OSG and IG3 when many unclassified stations appear to be transitional between the two. The proportions of variance removed by the first three components was 6.8%, 5.0%, and 3.8%.

PRINCIPAL COMPONENTS ANALYSIS

Analysis of the Covariance Matrix

Figure 16 shows the station projections (i.e., scores on the principal axes) derived from the principal components analysis of the covariance matrix. Staion groups MSG and IG1 are rather poorly separated while IG2 and IG3 are better resolved. Figure 17 (IG2, IG3, and OSG removed) shows the difficulties in the classification of MSG and IG1. In particular, Stations 37, 38, 73, and 924 seem to be almost as close to IG1 as they are to their normal group, MSG. Station 83 is closely allied to MSG while the affiliation of station 82 remains ambiguous. The positions of 61 and 62 indicate their typical affinity with IG1. Figure 18 shows a diffuse OSG with one member (Station 29) being markedly displaced towards MSG (as it was in the principal coordinates analysis using Czekanowski coefficient). IG3 is fairly well removed from IG1 and this time Station 10 appears to be better classified as a member of IG1. Again, Station 8 exists on the periphery of IG1. The proportions of variances removed by the first three components was 16.8%, 10.6%, and 7.2%.

Analysis of the Correlation Matrix

The projection of all stations onto principal axes derived from the correlation matrix is presented in Figure 19. It is surprising in that it is practically unipolar on the second axis, with only several members of OSG and several outliers being positioned near the lower end. Figure 20 (IG1 and MSG removed) confirms the usual trend of Stations 82 and 83 being positioned close to MSG and Stations 62 and 63 near IG1. Another addition to MSG under this analysis is the pair of possible transition members, Stations 64 and 70. From Figure 21 it appears that Stations 3, 8, and 10 may again be as closely linked with IG3 as they are with IG1, although divisions between these groups are perhaps somewhat arbitrary in the first place. The proportions of variance accounted for by the first three components was 15.2%, 8.7%, and 6.9%.

INVERSE ANALYSIS--THE CLUSTERING OF SPECIES

The results of the clustering of variables to form species groups is shown in Table 4, which gives the composition of 56 species groups suggested by the analysis and the feeding type and mobility of the group members, if known, based on Jumars and Fauchald (1977) and Feder *et al.* (1978). Again the size of the clusters (species groups) is arbitrary but tends to be as large as possible while still defining an assemblage of organisms whose station occurrences tend to coincide. To this end the two-way table of abundances of species (arranged according to potential cluster membership) at the different stations (arranged according to station-group membership) was used to define the species-cluster boundaries.

A summary of the standard two-way table is shown in Appendix V. The entries are termed cell densities and are defined as:

$$D = \frac{\sum_{i=1}^{n} \sum_{j=1}^{s} x_{ij}}{ns} ,$$

where n is the number of species in the cell, s is the number of stations in the cell, and x_{ij} is the number of the ith cell species found at the jth cell station. These entries directly indicate the concentration of a single species group for a single station group.

Statements concerning spatial patterning found among species groups are generally less satisfactory than those concerning station groups. One reason is that the geographic distribution of a species group must be a synthesis of the varying ranges of the constituent species which in themselves are not limited to single locations (as are the constituent stations of station groups). Secondly, the higher number (14) of major species groups leads to confusing results in the production of a conglomerate distribution map similar to those constructed for station groups. However, given the coherent spatial patterning characteristic of all station groups other than IG3, some generalizations concerning species group ranges may be made on the basis of the two-way table by using station group positions as indicators.

A condensed version of the cell density table is presented in Table 5, in which the densities of species groups with over four members are listed

Table 4. Species group membership as indicated by cluster analysis. Feeding type and mobility from Feder and Matheke (1978).

Group Number	Species Name	Feeding Type[1]	Mobility Type[2]
1	*Eteone spitsbergensis*	-	S
	Psolus phantapus	DF	S
	Onuphis geophiliformis	S	DM
	Eunice valens	DF	M
2	*Lysippe labiata*	DF	S
	Psephidia lordi	SF/S	DM
3	*Nicomache personata*	DF	S
	Astarte esquimalti	SF	DM
	Harmothoe imbricata	S	M
4	*Travisia brevis*	DF	M
	Paraphoxus obtusidens	DF	M
	Haploscoloplos panamensis		
	Protomedia grandimana	DF	-
5	*Anaidides mucosa*	P/DF	M
	Anonyx nugax	S	M
6	*Chone cincta*	SF	DM
7	*Cyclocardia crassidens*	SF	S
8	*Glycera capitata*	P/DF	M
	Aricidea suecica	DF	M
	Ampelisea escherichti	SF	S/DM
	Ampelisea furcigera	SF	S/DM
	Polydora socialis	DF	DM
	Phascolion strombi	DF	S
	Laonice cirrata	DF	DM
	Urothoe denticulata	SF	S/DM
	Odontogena borealis	SF	-
	Ninoe gemmea	DF	M
9	*Terebratalia crossei*	SF	S
	Modiolus modiolus		

---

[1] Feeding types: P = predator, S = scavenger, DF = detrital feeder, SF = suspension feeder.

[2] Mobility types: M = motile, DM = discreetly motile, S = sessile.

Table 4. Continued

Group Number	Species Name	Feeding Type	Mobility Type
10	*Peisidice aspera*	S	M
	Notoproctus pacifica	DF	S
	Ampelisea birulai	SF	S
	Golfingia margaritacea	DF	S
	Pista cristata	DF	S
11	*Spiophanes kroyeri*	DF	DM
	Laphanis boecki		DF
	Thysanoessa raschii	DF	M
12	*Diastylis* cf. *D. tetradon*	S	M
13	*Orchomene nugax*	S	M
14	*Nephtys rickettsi*	P	M
	Cucumaria calcigera	S	S
15	*Maldane glebiflex*	DF	S
16	*Aricidea uschakovi*	DF	M
	Lyonsia norvegica	SF	S
17	*Margarites olivaceous*	DF	M
18	*Chone gracilis*	SF	DM
	Admete couthouyi	SF	M
19	*Macoma lama*	DF	S
	Asterias ameurensis	P/S	M
	Cyclocardia ventricosa	SF	S
20	*Cistenides hyperborea*	DF	M
	Proclea emmi	DF	M
21	*Serripes groenlandicus*	SF	S
22	*Cossura longicirrata*	-	-
23	*Gattyana treadwelli*	S	M
	Polinices pallida	P	M
24	*Polynoe canadensis*	S	M
	Yoldia hyperborea	SD	M
	Artacama proboscidea	DF	DM

Table 4. Continued

Group Number	Species Name	Feeding Type	Mobility Type
25	*Sternaspis scutata*	DF	M
	Eudorella pacifica	DF/S	M
	Brada villosa	DF	DM
	Eteone longa	P	M
	Magelona pacifica	DF	DM
	Spio filicornis	DF	DM
	Phloe minuta	S	M
	Tharyx sp.	DF	S/DM
	Praxillella praetermissa	DF	S
	Capitella capitata	DF	M
	Harpinia gurjanovae	SF	M
	Nephtys ciliata	DF/P	M
	Macoma moesta alaskana	DF	S
	Axinopsida serricata	SF	S
	Praxillella gracilis	DF	-
26	*Nephtys punctata*	P	M
	Eudorella emarginata	SF/S	M
	Yoldia amygdalea	SF	M
	Bathymedon nanseni	DF/S	M
	Heteromastus filiformis	DF	M
27	*Aglaophamus rubilla anops*	DF/P	M
	Melita formosa	DF/S	M
	Priapulus caudatus	P	M
	Prionospio malmgreni	DF	DM
	Melita dentata	DF/S	M
	Ammotrypane aulogaster	DF	M
	Paraonis gracilis	DF	M
28	*Eudorellopsis integra*	DF/S	M
	Pontoporeia femorata	SF	S/DM
	Scalibregma inflatum	DF	M
	Byblis gaimardi	SF	S
	Haploscoloplos elongatus	DF	M
	Chaetozone setosa	DF	DM
	Macoma calcarea	DF	S
	Retusa obtusa	P	M
	Nucula tenuis	S	M
29	*Yoldia secunda*	DF	M
	Dacrydium pacificum	SF	S

Table 4. Continued

Group Number	Species Name	Feeding Type	Mobility Type
30	*Drilonereis falcata minor*	DF	M
	Paraphoxus simplex	SF	M
	Ophiura sarsi	DF/P	M
	Lumbrineris zonata	DF	M
	Harpinia tarasovi	SF	M
	Terebellides stroemi	DF	S
	Lumbrineris similabris	DF	M
	Clinocardium ciliatum	SF	S
	Nuculana pernula	DF	M
	Diamphiodia craterodmeta	-	DF
	Thyasira flexuosa	-	SF
	Maldana sarsi	DF	M
	Cistenides granulata	DF	M
	Solariella varicosa	S/P	M
31	*Photis spasskii*	DF	M
	Photis ninogradovi	DF	M
	Protomedia fasciatoides	DF	M
32	*Ampharete acutifrons*	DF	S
	Yoldia scissurata	DF	M
	Leucon nasica	DF/S	M
33	*Diastylis bidentala*	DF	S
34	*Polydora concharum*	DF/S	M
	Owenia fusiformis	SF/DF	-
35	*Chone infundibuliformis*	SF/DF	M
	Chone duneri	SF	DM
36	*Anaitides groenlandica*	P/DF	M
	Magelona japonica	DF	DM
	Euchone analis	SF	DM
37	*Anaitides maculata*	DF	M
	Glycinda armigera	P	M
	Mysella aleutica	SF/DF	-
	Paraphoxus milleri	SF	M
38	*Cylichna occulata*	DF	M
	Protomedia chaelata	DF	M
	Mysella tumida	SF/DF	-

Table 4. Continued

Group Number	Species Name	Feeding Type	Mobility Type
39	*Tachyrynchus erosus*	S/P	M
	Westwoodilla coecula	DF/S	M
	Rhodine loveni	DF	S
	Nephtys caeca	P	M
	Diastylis alaskensis	DF/S	M
	Orchomene lapidula	S	M
40	*Cyclocardia crebricostata*	SF	S
	Polinices nanus	P	M
	Spiophanes bombyx	DF	DM
	Haustorious eous	SF	S/DM
	Ophelia limacina	DF	M
	Echinarachnius parma	DF	M
	Tellina lutea alternidentata	DF	M
	Travisia forbesii	DF	DM
	Glycinde picta	P	M
	Scoloplos armigera	DF	DM
	Nephtys longasetosa	P	M
	Solariella obscura	S/P	M
	Eudorellopsis deformis	DF/S	M
	Ampelisca macrocephala	SF	S
	Hippomedon kurilious	S/DF	M
	Cylichna alba	P	M
	Ampharete arctica	DF	S
	Myriochele heeri	DF	S
	Corophium crassicorne	SF	S
41	*Spisula polynyma*	SF	M
42	*Protomedia fascata*	DF	M
43	*Spiophanes cirrata*	DF	DM
	Acila castrensis	SF/DF	M
44	*Cistenides brevicoma*	DF	-
	Amphipholis pugetana	DF	M
45	*Balanus crenatus*	SF	S
	Haustorious eous	SF	S/DM
46	*Macoma brota*	DF	S
	Harpinia kobjakovae	SF	M
47	*Pista maculata*	DF	S

Table 4. Continued

Group Number	Species Name	Feeding Type	Mobility Type
48	*Argissa hamatipes*	-	-
49	*Boltenia ovifera*	SF	S
	Boltenia villosa	SF	S
	Pseudopotamilla rentiformis	SF	S
	Ericthonius hunteri	SF	DM
50	*Astarte polaris*	SF	S
51	*Monoculodes zernovi*	DF/S	M
52	*Neptunea ventricosa*	S/DF	M
53	*Balanus hesperius*	SF	S
54	*Echinarachnius parma*	DF	M
55	*Neptunea heros*	S/DF	M
56	*Balanus rostratus*	SF	S

Table 5. Cell densities of major species groups for major station groups identified by cluster analysis of Bering Sea infaunal data.

Species Group	No. of Species in Group	Station Group IG1	IG2	IG3	MSG	OSG
1	4	0	0	.1	0	.4
4	4	1.2	1.5	33.7	.6	.1
8	10	.1	0	.1	.1	6.2
10	5	0	0	.2	0	.3
24	3	.8	0	.2	10.2	10.1
25	15	26.0	.3	4.3	40.1	14.6
26	5	2.2	0	.6	11.6	5.2
27	7	.3	.3	.2	3.9	.6
28	9	10.9	.1	2.7	45.5	26.0
30	14	.3	0	.3	6.3	42.7
37	4	1.9	0	1.2	.2	.6
39	9	29.1	8.0	3.3	20.2	.3
40	16	30.4	12.3	13.3	2.8	7.4
49	4	0	0	0	0	.1

for the five major station groups. This table is used to describe briefly the areas in which the species groups are found. Stations not classified as part of the major station groups have been incorporated into this discussion when significant concentrations of a species group were noted.

Group 1 -- Found mainly in the shelf break area with a slight representation in the nearshore stations of IG3.

Group 4 -- High numbers in the nearshore/Bristol Bay stations of IG3.

Group 8 -- The only significant concentrations are in the shelf edge group OSG.

Group 10 -- Found predominantly offshore and in the scattered nearshore/Bristol Bay stations of IG3. By far the most important concentration is at Station 35 (density at this station is 70 individuals per square meter).

Group 24 -- Richest in the midshelf area with concentrations decreasing gradually seaward and much more rapidly shoreward. There is also an appreciable occurrence in the pair of Stations 82 and 83.

Group 25 -- Richest in the midshelf regions with generally lower numbers shoreward and seaward. Nearshore abundances are distinctly higher than those from shelf break stations.

Group 26 -- As in 24 with highest density values for the pair of Stations 64 and 70 located north of the Pribilof Islands.

Group 27 -- The only distinct concentrations are in the shelf edge group (OSG) and the northeast pair of stations, 82 and 83.

Group 28 -- Similar to 26 with high densities in station pairs 82 and 83, 64 and 70, and 30 and 49, in order of decreasing density.

Group 30 -- Richest near the shelf break with decreasing concentrations over the shelf. High densities are also seen at the pair of Stations 64 and 70 and, to a lesser degree, at the pair of Stations 47 and 55.

Group 37 -- Mainly found in water of depths less than 50 m, but the overall distribution is not clearly defined.

Group 39 -- Largely nearshore and includes Bristol Bay, with some representation in the midshelf area (MSG) and in the pair of Stations 47 and 55, near the Pribilof Islands.

Group 40 -- Ubiquitous, with lower numbers in the midshelf and shelf break areas and medium densities in the station pair 47 and 55.

Group 49 -- Predominantly shelf break with extremely high densities (32 individuals per square meter) at the unclassified Station 4 near the Alaska Peninsula.

TRENDS IN ABUNDANCE AND DIVERSITY

Station count and wet weight profiles are found in Table 6. The number of individuals per square meter ranged from 420 to 4,680. Station wet weights were generally low, ranging from 9.3 to 2,420.1 g/m^2, with values of over 200 g/m^2 occurring at only 14 stations.

Very high wet weight figures are usually attributable to: (1) the sampling of dense aggregates of bivalves, or (2) the sampling of one or more large echinoderms. Ideally, wet weights should reflect biomass, but in both the situations just mentioned, the high weights result from the inclusion of either shell material or exoskeleton in the weight. The high wet weights associated with Stations 5, 6, and 7 of IG2 and the generally high figures from IG2 ($\bar{x}$ = 517 g/m^2) coupled with the very low figures for the number of individuals per m^2 ($\bar{x}$ = 506) are an example of this problem. At Station 5, most of the weight was associated with eighteen (18) individuals of the pelecypod *Tellina lutea alternidentata*. The high wet weight of Station 6 is chiefly due to one large asteroid, *Asterias ameurensis* and the high Station 7 weight resulted from a large haul (78 in seven grabs) of the sand dollar, *Echinarachnius parma*.

While formation of shell and skeletal material does represent an energy requirement of the benthos, such material should not be confused with biomass, which carries an attendant respiratory requirement. Thus, a simple extension of wet weights to benthic biomass or productivity may not be made without some attempt to evaluate the magnitude of interference from non-organic materials. It should also be realized that sampling of aggregations and large individuals is a rare event and may not be considered to be representative.

Abundance and wet weight data for the five main groups are summarized in Table 7. The lower wet weight per square meter figures for MSG, OSG, and

Table 6. Total numbers of individuals and taxa, total wet weight, dominance, and diversity indices calculated for Bering Sea benthic stations.

Station Group & Station		Total Numbers m^2	Total Wet Weight g/m^2	Simpson Dominance Index*	Shannon Diversity Index*	Brillouin Diversity Index*	Number of Taxa
IG1	1	3570/3396	726.0	.073/.080	3.28/3.11	3.23/3.06	106/84
	3	1130/ 938	40.5	.045/.057	3.62/3.37	3.48/3.24	87/66
	8	3924/3864	32.5	.063/.086	2.91/2.85	2.87/2.81	71/61
	10	762/ 682	167.0	.053/.064	3.43/3.19	3.28/3.06	66/52
	11	1044/ 922	28.2	.038/.048	3.91/3.68	3.74/3.52	104/86
	12	2254/2162	33.3	.085/.093	3.14/2.99	3.07/2.93	86/71
	20	2622/2540	111.8	.092/.098	3.04/2.92	2.98/2.86	87/73
	25	2056/1967	82.5	.083/.091	3.11/2.96	3.04/2.90	83/67
	27	2152/2096	84.0	.131/.138	2.64/2.53	2.59/2.48	61/51
	39	1964/1806	9.3	.111/.130	2.90/2.67	2.83/2.61	73/57
	40	2478/2385	17.2	.101/.109	2.85/2.70	2.80/2.65	81/63
	41	4464/4221	168.7	.201/.224	2.54/2.37	2.51/2.34	88/70
	42	1134/1086	111.0	.053/.057	3.52/3.39	3.39/3.28	82/71
	43	3022/2770	137.5	.074/.087	3.24/3.05	3.18/3.00	89/74
	59	2428/2260	144.5	.097/.111	3.17/2.99	3.19/2.93	73/60
IG2	5	690/ 630	714.5	.098/.116	2.70/2.48	2.62/2.40	28/22
	6	690/ 546	925.3	.118/.178	2.71/2.21	2.60/2.12	43/30
	7	227/ 217	264.9	.269/.295	1.98/1.81	.83/1.68	25/19
	23	420/ 392	164.3	.085/.097	2.85/2.66	2.72/2.54	35/27
IG3	9	1294/1054	202.9	.123/.155	2.94/2.76	2.83/2.65	89/73
	22	709/ 590	121.9	.044/.053	3.65/3.45	3.45/3.26	98/77
	57	2504/1793	40.5	.129/.181	2.52/2.28	2.47/2.22	77/65
	60	531/ 474	139.5	.108/.133	2.99/2.71	2.80/2.54	71/57

---

*Double entries represent values derived from consideration of all organisms identified to phylum and, secondly, all taxa identified to genus.

Table 6. Continued

Station Group & Station	Total Numbers m^2	Total Wet Weight g/m^2	Simpson Dominance Index*	Shannon Diversity Index*	Brillouin Diversity Index*	Number of Taxa
MSG 19	4166/4044	268.9	.081/.086	3.19/3.07	3.13/3.02	116/100
28	4394/4326	2420.1	.479/.494	1.77/1.68	.73/1.64	91/75
37	652/ 628	33.4	.114/.123	3.01/2.88	2.88/2.76	54/45
38	612/ 588	639.5	.195/.211	2.65/2.51	2.51/2.37	55/48
45	2606/2454	95.0	.099/.112	2.89/2.72	2.84/2.67	77/65
63	2574/2462	156.7	.084/.091	3.02/2.91	2.97/2.86	65/56
71	2708/2626	175.9	.091/.097	2.94/2.83	2.89/2.79	64/53
72	1592/1490	122.4	.067/.075	3.21/3.06	3.13/2.99	63/52
73	734/ 658	14.2	.062/.076	3.33/3.10	3.19/2.97	59/48
924	644/ 598	283.6	.082/.094	3.10/2.96	2.95/2.84	54/48
935	2406/2328	98.8	.090/.095	2.99/2.89	2.94/2.85	59/51
937	1566/1512	76.4	.097/.104	2.87/2.74	2.80/2.68	55/43
939	1250/1170	192.9	.091/.102	2.80/2.62	2.74/2.57	44/33
941	836/ 794	187.6	.077/.085	2.94/2.80	2.84/2.71	43/36
942	820/ 793	207.5	.067/.071	2.95/2.85	2.88/2.76	39/33
OSG 16	674/ 630	23.1	.077/.087	3.27/3.10	3.11/2.95	66/55
17	872/ 818	30.5	.051/.057	3.45/3.29	3.30/3.15	74/63
18	1632/1586	83.7	.081/.085	3.33/3.23	3.72/3.13	100/89
29	4454/4344	334.2	.149/.157	2.79/2.68	2.75/2.64	90/76
31	1035/ 927	20.9	.033/.040	3.96/3.73	3.77/3.56	130/108
36	1178/1034	44.9	.048/.053	3.65/3.57	3.51/3.43	92/82
65	960/ 940	34.0	.100/.104	3.17/3.10	3.05/2.98	69/63
2	2877/2120	983.5	.458/.784	1.35/0.66	1.32/0.64	34/23
4	1167/ 960	671.4	.043/.058	3.73/3.36	3.59/3.25	82/59
13	547/ 482	36.0	.031/.038	3.91/3.72	3.66/3.98	86/74
14	1516/ 494	32.5	.171/.034	2.92/3.75	2.82/3.52	96/71

Table 6. Continued

Station Group & Station	Total Numbers m^2	Total Wet Weight g/m^2	Simpson Dominance Index*	Shannon Diversity Index*	Brillouin Diversity Index*	Number of Taxa
15	588/ 332	42.3	.153/.141	2.76/2.81	2.61/2.62	55/42
24	1973/1825	578.8	.117/.136	2.94/2.66	2.86/2.60	78/55
35	1260/1004	81.9	.036/.047	3.90/3.65	3.75/3.50	115/90
30	626/ 598	31.3	.221/.242	2.20/2.04	2.12/1.96	33/26
49	577/ 515	19.2	.091/.113	3.01/2.73	3.89/2.61	48/36
47	4680/4336	100.0	.040/.046	3.63/3.44	3.58/3.40	103/80
55	3330/3030	106.0	.162/.194	2.94/2.67	2.88/2.63	97/76
61	622/ 584	30.5	.083/.094	3.13/2.95	2.98/2.82	56/46
62	1724/1668	52.2	.281/.300	2.34/2.19	2.27/2.13	65/54
64	1757/	196.2	.165/	2.50/	2.45/	56/
70	1914/ 967	110.3	.173/.070	2.68/3.03	2.61/2.94	54/39
82	1120/ 774	116.7	.105/.141	2.84/2.65	3.58/3.40	49/38
83	2282/2076	106.2	.087/.103	3.04/2.83	2.88/2.63	67/52

Table 7. Average abundance, wet weight, and number of taxa for major station groups identified in Bering Sea infaunal studies.

Station Group	Average Number* of Individuals/m^2	Average* Wet Weight g/m^2	Average Number of Taxa per Station
IG1	2333	126.3/83.46[1]	67.1
IG2	506	517.3	24.5
IG3	1259	126.2	68.0
MSG	1837	331.4/182.3[2]	52.4
OSG	1543	81.6/39.5[3]	76.6

---

[1] Lower figure omits high value for Station 1.

[2] Lower figure omits high value for Station 28.

[3] Lower figure omits high value for Station 29.

*Based on all organisms identified to phylum level.

IG1 reflect the removal of a single station with extremely high wet weight values (three to four times higher than the next highest value). IG1 and OSG are areas of low wet weight while IG3 and MSG are progressively higher. IG2 is difficult to classify since wet weights from three of the four stations are completely dominated by non-organic material.

A listing of station abundance and diversity profiles is also presented in Table 6. Diversities have been calculated twice, initially using data representing all individuals identified to phylum level and then data that include only individuals identified to at least genus level. One may expect the former scheme to include the same taxa under different levels of classification and so overestimate diversity by including too many species. The latter method would produce an error in the opposite direction.

The following remarks are directed towards comparisons of estimated community diversity and are therefore oriented around the Shannon index (see section on diversity in Methods). Average values of the Shannon diversity for the five station groups are listed in Table 8. The species richness results are also included in this table. It is apparent that the diversity of IG2 is quite low, that of OSG the highest, and those of IG1, IG2, and MSG practically the same. In fact, given the lack of information on variance, the latter three cannot be safely separated on the basis of diversity.

TROPHIC STRUCTURE

Results from investigations into the trophic structure of the main station groups are shown in Table 9, which lists both numbers of species in different trophic categories and the average numbers of individuals per station in the assigned classes, for the five major station groups. Table 10 is derived from Table 9 and illustrates the differing ratios in which suspension feeding organisms are found in the different station groups. Emphasis has been placed on the occurrence of suspension feeders as their distributions have often been linked to substrate changes and changes in diversity.

Table 8. Average species richness and diversity for station groups identified by Bering Sea infaunal studies.

Station Group	Total Number* of Species	Average Number* of Individuals/m^2	Average Diversity (Shannon Index)	Species Richness
IG1	126	1408.1	2.98	5.92
IG2	32	299.9	2.29	2.56
IG3	90	756.6	2.80	7.08
MSG	116	1625.8	2.70	5.27
OSG	132	651.9	3.24	7.35

---

*Based only on organisms used as variables in numerical analysis.

Table 9. Total numbers of species[1] found in groups and number of individuals/m^2 per station in groups, by feeding[2] and mobility[3] type[4].

Station Group	S P M		DF M		DF DM	
	No. of Species	Individuals per m^2/station	No. of Species	Individuals per m^2/station	No. of Species	Individuals per m^2/station
IG1	36	285.9	41	460.0	10	243.6
IG2	15	41.9	10	158.9	3	54.1
IG3	27	137.8	26	335.4	7	67.9
MSG	34	218.6	35	650.7	10	56.3
OSG	34	90.5	41	378.4	10	18.5

Station Group	DF S		SF M		SF DM		SF S	
	No. of Species	Individuals per m^2/station	No. of Species	Individuals per m^2/station	No. of Species	Individuals per m^2/station	No. of Species	Individuals per m^2/station
IG1	14	201.9	4	41.3	11	76.2	10	99.9
IG2	3	35.4	0	0	0	0	1	8.7
IG3	11	59.8	3	59.4	7	15.1	9	81.1
MSG	17	197.5	4	98.3	9	76.6	7	387.8
OSG	18	43.2	7	15.9	8	14.3	14	91.1

---

[1] Based on 180 species used in numerical analysis.

[2] Feeding types: P = predator, S = scavenger, DF = detrital feeder, SF = suspension feeder.

[3] Mobility types: M = motile, DM = discreetly motile, S = sessile.

[4] Feeding type and mobility types after Feder *et al.* (1978).

Table 10. Proportions of suspension-feeding (SF) individuals found in station groups*.

Station Group	Total Number of Species	SF Species	SF Species / Other Types	Individuals per m^2/station	SF Individuals per m^2/station	Mean SF Individuals / Mean Other Types
IG1	126	25	.198	1408.1	217.4	.183
IG2	32	1	.031	299.9	8.7	.031
IG3	90	19	.268	756.5	155.6	.259
MSG	116	20	.208	1625.8	502.7	.448
OSG	132	29	.282	651.9	121.3	.229

---

*Based only on organisms used in numerical analysis.

Several interesting contrasts between groups are apparent: (a) IG2 possesses relatively few suspension feeding organisms, both in terms of the number of species and number of individuals found; (b) OSG is host to the greatest number of suspension feeding species although they are not numerically abundant; and (c) MSG, which is represented by a fairly high number of suspension feeding species is most obvious for the extremely high fraction of both suspension feeding individuals and sessile individuals present.

SEDIMENT ANALYSIS

Table 11 summarizes particle size data for the five major station groups (Hoskin, pers. comm.; data submitted to NOAA under OCSEAP program, RU #291/292). Not all stations are included as data were unavailable for some. An overview of the particle size distribution is shown in Figure 22 (from Sharma, unpublished). A complete listing of sediment data for the major station groups is presented in Table 12.

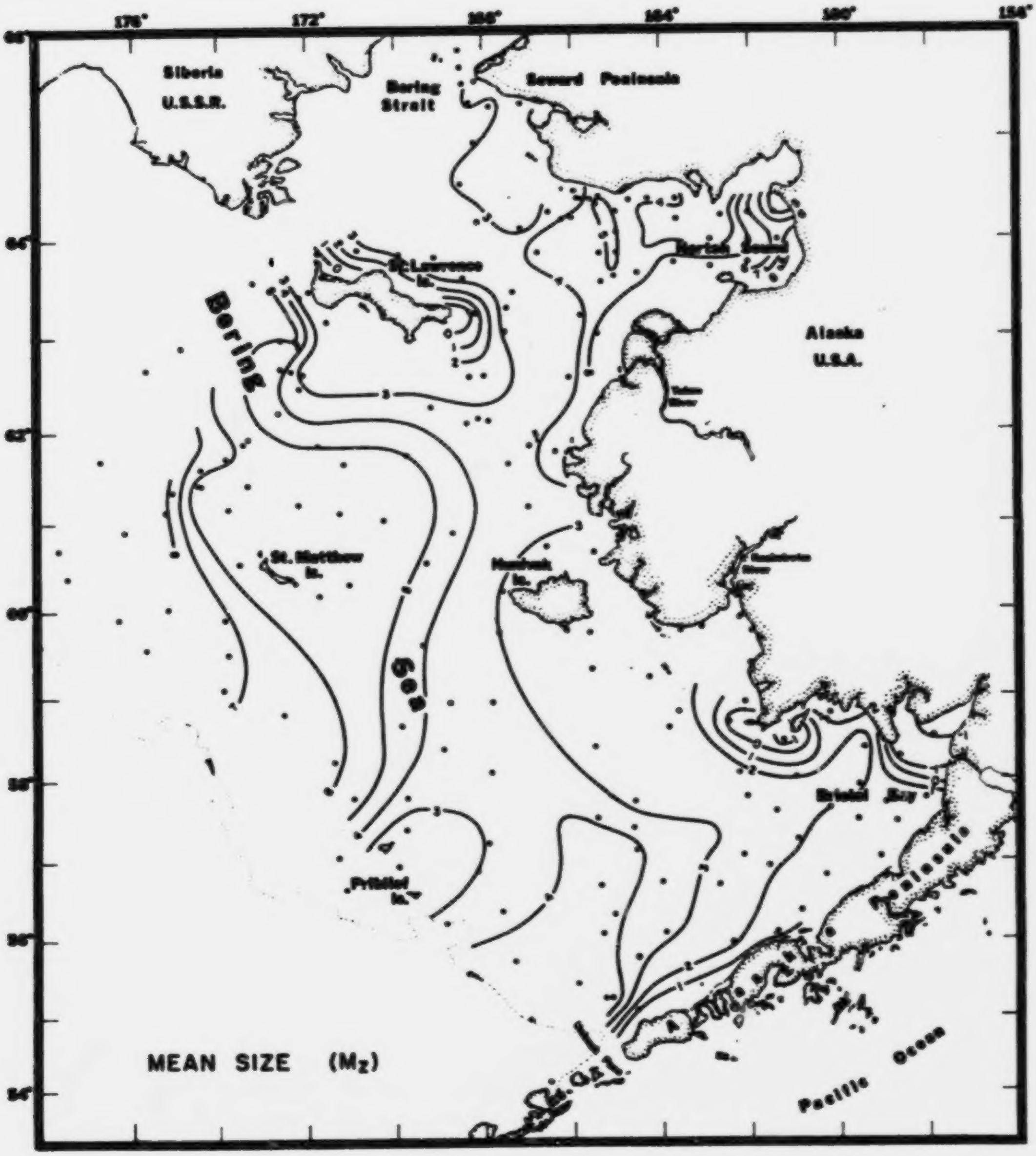
Sediment types were found to vary between the major station groups. Since information on the variance of this data is unavailable, no attempt was made to separate these station groups on a statistical basis. Thus, a simple description of the sediment types for the major station groups follows. Unless otherwise noted, sand/gravel fractions are composed primarily of the sand fraction as the occurrence of non-zero gravel percentages in the sampled stations was rare.

IG1 -- A high percentage of sand and gravel is found in these stations, indicating an intermediate position between groups MSG/OSG and IG2/IG3. The low standard deviation for this group may be a sampling artifact as the sample size for this group is the largest (n = 16, Stations 61 and 62 included).

IG2 -- The most obvious attribute of this group is the high percentage of sand and gravel ($\bar{x}$ = 98.86%) found at all stations. Stations 5 and 7 registered 77.03% and 18.49% of their respective totals as actual gravel. IG2 is probably separable from the other station groups on this parameter alone.

Table 11. Average mean and standard deviation for sediment parameters characterizing station groups.

Station Group	Gravel/Sand		Silt		Clay	
	Mean %	Standard Deviation	Mean %	Standard Deviation	Mean %	Standard Deviation
IG1	85.2	8.7	7.7	6.2	6.9	4.8
IG2	98.8	1.1	0.2	0.2	0.8	0.9
IG3	91.4	8.0	4.0	5.8	2.8	3.2
MSG	62.4	16.0	29.1	14.6	7.9	1.5
OSG	59.9	14.5	31.2	12.4	9.2	2.6



176°
172°
168°
164°
160°
156°
66°
64°
62°
60°
58°
56°
54°
Siberia
U.S.S.R.
Bering
Strait
Seward Peninsula
St. Lawrence
Is.
Norton Sound
Bering
Sea
Alaska
U.S.A.
St. Matthew
Is.
Nunivak
Is.
Bristol Bay
Pribilof
Is.
Peninsula
Pacific Ocean
MEAN SIZE (M$_z$)

Figure 22. Mean particle size (ϕ units) of sediments of the eastern Bering Sea shelf (from Sharma, unpub.).

BEST DOCUMENT AVAILABLE

Table 12. Sediment data for Bering Sea stations classified into station groups by cluster analysis*.

Station Group	Station	% Gravel/Sand	% Silt	% Clay
IG1	1	72.61	19.57	7.82
	8	99.85	.15	0.0
	10	80.90	8.68	10.42
	11	84.67	5.66	9.67
	20	85.79	6.41	7.80
	25	99.44	.26	.30
	27	84.77	8.25	6.98
	39	76.75	15.37	7.90
	40	84.04	7.65	8.30
	41	96.91	.63	2.46
	42	97.51	1.26	1.22
	43	85.00	7.47	7.26
	57	80.81	12.47	6.72
	59	83.13	9.18	7.64
	61	77.08	2.66	20.26
	62	74.72	18.45	6.84
IG2	5	99.86	.10	.04
	6	97.61	.61	1.78
	7	99.90	.11	0.0
	23	98.08	.23	1.69
IG3	9	99.97	.02	0.0
	22	90.70	2.80	6.50
	60	94.31	3.52	2.28
	57	80.81	12.47	6.72
MSG	19	59.27	33.28	7.45
	28	53.42	36.85	9.74
	37	65.63	25.70	8.66
	38	47.07	44.28	8.65
	45	59.40	34.29	6.31
	71	69.01	22.95	8.04
	72	46.05	45.06	8.89
	82	88.17	5.20	6.63
	83	50.82	39.43	9.75
	935	90.74	4.17	4.99
OSG	16	62.34	28.01	9.65
	17	36.44	49.92	13.64
	29	62.05	30.99	6.96
	31	76.90	15.27	7.83
	65	59.59	32.13	8.28

---

*Data after Hoskin (pers. comm.) submitted to NOAA under OCSEAP Program, 1976.

IG3 -- Stations from this group show the nearshore trait of high sand and gravel content ($\bar{x}$ = 91.45% sand/gravel and 8.05% for silt). These figures indicate a resemblance to IG1, albeit with a significant increase of sand/gravel content.

MSG -- Sediments from this group show a high value for silt and clay fractions. The high variance suggests a heterogeneity not found in the other station groups. For example, in the silt fraction values range from 4.17% (Station 935) to 45.06% (Station 72).

OSG -- Sediment samples from OSG, with sand/gravel percentages ranging from 36% to 77%, did not show the degree of consistency found in the nearshore groups. This group is probably not safely separable from MSG on the basis of the parameters chosen. It shows lower concentrations ($\bar{x}$ = 59.96%) of sand and correspondingly higher ($\bar{x}$ = 31.26%) percentages of silt than were found in MSG. This increase in the fraction of fine-grained sediments in OSG is in accord with the postulated transport of fine particles to offshore areas.

CONCLUDING DISCUSSION

THE DETERMINATION OF FINAL STATION GROUP BOUNDARIES

Inspection of the plots resulting from principal coordinate and principal component analyses (Figures 10, 13, 16, 19) reveals a problem often encountered when using ordination techniques to produce station groupings. If one envisions these plots without the different symbols marking the affinities already suggested by the cluster analysis, it becomes apparent that gradations between major groups makes group differentiation (if groups may be distinguished) difficult if not impossible. This result is probably due as much to the large number of stations involved as it is to any inherent lack of structure in the data.

Chardy *et al.* (1976) used ordination methods, unaided by other types of analysis, to classify benthic infaunal distributions off the Brittany coast. They were successful in their efforts to discern community relations, but were dealing with only 30 stations. Given the larger number of stations involved in the present study, the use of ordination methods largely in the capacity of a confirmation of the cluster analysis results is unavoidable. Other uses of ordination methods are: (1) in defining the relations between groups previously delineated by cluster analysis and (2) in determining the relationships between outliers and main groups or occasional group members to core group members. In this case the graphic output of the ordination methods is especially useful.

Minor modifications of the cluster interpretations are suggested by the results of ordination output. In particular, Stations 61 and 62 invariably exhibit a strong affinity for IG1, while Stations 82 and 83 are generally found near MSG. Stations 3, 8, and 10 are strongly transitional between Groups IG1 and IG3.

A map of the communities incorporating the combined information derived from cluster analysis and ordination techniques is presented in Figure 23. The link between Station 4 and IG3 is not strong, so Station 4 has been left outside of IG3. The transitional nature of Stations 3, 8, and 10 is indicated by the dashed line linking them to MSG. Stations 61 and 62 and Stations 82 and 83 have been incorporated in IG1 and MSG respectively. Although not indicated on the map, the entire OSG assemblage is less distinct than any of the other major groups. The similarities of Stations 14 and 35 to OSG are not acknowledged as these links are admittedly tenuous.

Most techniques used suggested the same relationship between outliers and the core groups. A summary of the affinities of unclassified singleton stations and station pairs to the major station groups is presented in Table 13.

Stations 2 and 4 are weakly linked to each other and all the inshore station groups. Stations 14 and 15 are also linked to each other and more generally to OSG. This tie to the other shelf group is consistent with their position near the shelf edge, although considering the extreme water depth associated with Station 15 (1,500 m), it is surprising that Station 15 shows a similarity to any of the other stations or groups. Station 24 is characterized by a fauna that is dissimilar to most other stations and the relationship between 24 and the other stations and groups remains ambiguous. During collection, the grabs from this station were noticeably

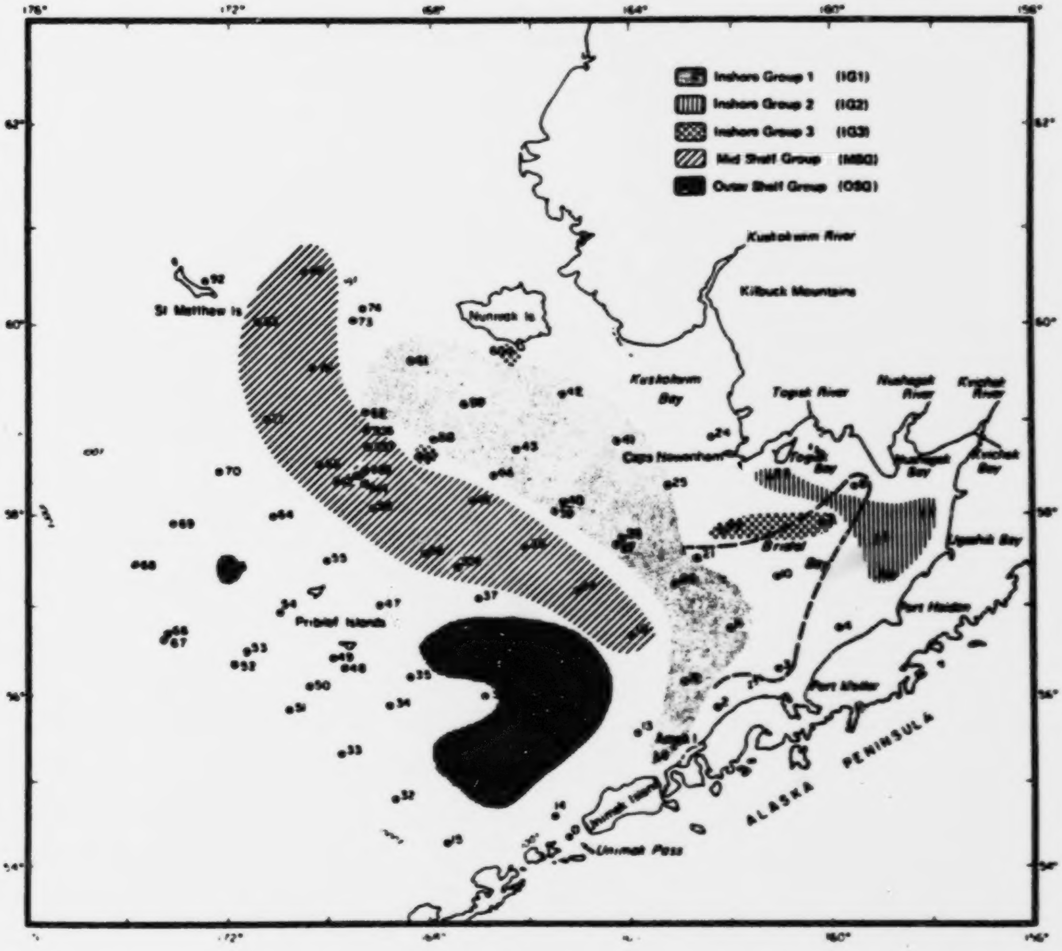

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Inshore Group 1 (IG1)
Inshore Group 2 (IG2)
Inshore Group 3 (IG3)
Mid Shelf Group (MSG)
Outer Shelf Group (OSG)
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 23. Station groups delineated by the combined use of cluster, principal components, and principal coordinates analyses. The dashed line linking stations 3, 8, and 10 to Inshore Group 1 indicate that these stations are only weakly associated with Inshore Group 1.

Table 13. Bering Sea benthic stations not classified by cluster analysis at .30 similarity level. Station affinities are indicated by cluster, principal components, and principal coordinates analyses.

	Type of Analysis and Indicated Affinity					
	Cluster Analysis		Principal Coordinates Analysis		Principal Components Analysis	
Unclassified Stations	Czekanowski Distance	Canberra Metric Distance	Czekanowski Distance	Canberra Metric Distance	Covariance Matrix	Correlation Matrix
2	none	IG2*	IG1,IG3,4	none	IG2,14,15	13,15,30,49
4	none	IG2*	IG1,IG3,2	IG1	14,15,IG2*	IG2
13	IG3	14,15	none	14,35	none	2,15,30,49
14	15,35	15,35	13,15	35,OSG	15	35,OSG
15	none	13,14	13,14	14,35	OSG	2,13,30,49
24	none	none	IG1	55*	61,IG1*	MSG
35	OSG*	14,15	30,OSG*	14	none	14,OSG
30,49	64,70,OSG	none	35,OSG	OSG	OSG	2,13,15
47,55	IG1	IG1,IG3*	24,47	MSG*	IG1*	MSG*,IG1*
64,70	OSG	MSG	29,47	29,18,OSG*	MSG*	MSG*

*Indicates a weak link to the stations or groups noted.

BEST DOCUMENT AVAILABLE

atypical for the varied substrate type brought up. Given the proximity of Station 24 to the mouth of the Kuskokwim River and the Alaskan coast, it is possible that ice rafting tends to maintain a significant heterogeneity in the substrate. Station 35 is clearly most similar to Stations 30, 49, and 15 and to OSG.

With the exception of the pair of Stations 30 and 49 (which are decidedly shelf break in orientation), the station pairs that were suggested (Table 3) are not amenable to easy classification. Stations 47 and 55 are weakly associated with MSG and IG1. Stations 64 and 70 are more closely related to the midshelf group and to several stations from OSG (i.e., Stations 18 and 29). Stations 18 and 29 are further from the shelf break than are any other members of OSG. This positioning suggests a link to 64 and 70, which are also removed from the shelf edge.

THE INTERPRETATION OF THE RESULTS OF ORDINATION

Some insight into the interactions between ordination procedures may be obtained from an examination of the above-mentioned station affinities. The associations of Stations 82 and 83 are illustrative. Station 83 is clearly the more diverse of the two, with an enriched fauna in terms of both the number of species and number of individuals (Table 6) present at the station. Under analysis of the principal components of the covariance matrix, MSG is split into two contingents, the smaller composed of Stations 37, 38, 73, and 924 (Figure 17). Station 82 projects onto the first axis in the general vicinity of these four stations, while Station 83 is found among the rest of MSG. Stations 37, 38, 73, and 924 show the lowest number of individuals/m^2 for stations in IG1, while Station 82 has only half the number of individuals that 83 has.

The positions of 82 and 83 relative to the rest of MSG reverse under the complementary ordering (i.e., principal components of the correlation matrix). Station 83 is now found on the fringe of MSG while Station 82 is nearer the group center (Figure 19). The explanation for this effect lies in the effect of the correlation coefficient on the larger numbers of individuals found at Station 83. An important point in this interpretation is that the stations are largely populated by the same species; hence, their greatest similarity is to each other.

A result less easily explained is the response of OSG to ordination. Stations 29 and 18 are found displaced from the rest of OSG by principal coordinates of the Czekanowski distance matrix (Figures 12 and 18) and the principal components of the covariance matrix. Again, the complementary techniques involving reduction in the effects of dominance and abundance leads to the migration of Stations 29 and 18 towards the rest of OSG. This is not difficult to explain since Stations 18 and 29 register the greatest number of individuals per square meter in the group (Table 14) and are among the stations showing the lowest Brillouin diversity for OSG.

Use of techniques that reduce the effect of high abundances and dominance would be expected to result in a more compact OSG. It is difficult to say whether or not OSG is more compact in Figure 19 (based on the principal components of the correlation matrix) than in Figure 18 (based on the principal components of the covariance matrix) as fully half of this axis is involved in removing variance associated with OSG. A complete examination of this situation would require an analysis of the actual components extracted from the correlation matrix, but this cursory view leads to the knowledge that OSG is intrinsically more heterogeneous than the other station groups in terms of abundances. Since OSG is also fairly well separated by the principal coordinates analysis based on the Canberra metric coefficient (Figure 13), it seems likely that the abundance differences are in species held in common by most stations in the group. If these species were not constantly occurring within the group, then such a change in distance measure would not be expected to greatly change the station projections relative to other members in the group.

The view of Stations 3, 8, and 10 is also complicated. If it may be assumed that differences within a station group are primarily based on abundances rather than species composition, we would expect the most disparate stations (compared to other stations in the group) in terms of the numbers of individuals present (i.e., Stations 3 and 10; Table 14) to be affected most strongly by the correlation standardization. Also,

Table 14. Dominance, diversity, and species richness for Bering Sea stations classified into major station groups. Calculations based on 180 species used in cluster and ordination analyses.

Station Group	Station	Brillouin Diversity Index	Simpson Dominance Index	Total Number of Species	Total Number of Individuals/m^2	Species Richness
IG1	1	2.91	.078	53	2354	6.70
	3	2.81	.083	39	752	5.74
	8	2.61	.105	40	2382	5.02
	10	2.84	.070	34	446	5.41
	11	2.83	.099	45	578	6.92
	12	2.54	.145	45	1460	6.04
	20	2.79	.095	44	932	6.29
	25	2.62	.118	44	1674	5.79
	27	2.16	.178	33	1098	4.57
	39	2.53	.114	37	1154	5.11
	40	2.52	.122	45	1410	6.07
	41	1.87	.303	49	3570	5.87
	42	3.05	.070	54	960	7.72
	43	2.71	.111	46	2240	5.83
	59	2.99	.065	43	1320	5.85
IG2	5	2.25	.125	16	460	2.45
	6	1.76	.227	17	296	2.81
	7	1.35	.378	13	190	2.29
	23	2.00	.170	16	250	2.72
IG3	9	2.41	.178	50	984	7.11
	22	2.76	.065	50	525	7.82
	57	1.93	.246	44	1370	5.95
	60	2.19	.184	33	318	7.46
MSG	19	2.72	.101	58	3706	6.94
	28	1.40	.545	50	4120	5.89
	37	2.87	.061	32	358	5.27
	38	2.17	.241	38	548	5.87
	45	2.51	.125	50	2306	6.33
	63	2.57	.114	40	2178	5.07
	71	2.72	.100	43	2578	5.35
	72	2.73	.094	39	1320	5.29
	73	2.59	.086	35	492	5.48

Table 14. Continued

Station Group	Station	Brillouin Diversity Index	Simpson Dominance Index	Total Number of Species	Total Number of Individuals/m^2	Species Richness
MSG	924	2.60	.113	37	538	5.73
	935	2.66	.152	42	2126	5.35
	937	2.57	.112	36	1452	4.81
	939	2.51	.105	29	1154	3.97
	941	2.56	.094	27	754	3.92
	942	2.64	.078	25	758	3.62
OSG	16	2.72	.106	40	562	6.16
	17	2.84	.071	40	732	5.91
	18	2.81	.104	56	1438	7.56
	29	2.50	.168	54	4198	6.35
	31	3.27	.050	72	816	10.74
	36	3.14	.068	59	900	8.53
	65	2.63	.370	43	814	6.27

stations exhibiting the highest degree of dominance will respond to differences in distance measure. IG1 is poorly defined by the covariance-based analysis (Figure 16) with Stations 3, 8, and 10 seemingly far removed from the group centroid. Definition is improved by the correlation standardization (Figure 19) and the distances between 3 and 10 and the group centroid have reversed. Station 8 seems unaffected. A similar trend occurs in the principal coordinate solutions as Stations 3 and 10 shift to nearer the group centroid when using a dominance-reducing distance measure (the Canberra metric) and Station 8 remains in the group periphery. The Simpson dominances for these stations (3, 8, and 10), are low (Table 14); thus, the contributions of several key dominant species at other stations in the group must have been reduced.

The different ordination alternatives lead to rearrangements of the stations within a particular group, while the relations of the groups to each other are generally constant. Differences between (as opposed to within) groups are largely determined by species composition rather than by abundances of species held in common. It is probable that the distance between Station 8 and the rest of the group was largely determined by species differences, a hypothesis that is in part borne out by inspection of the raw data and also by the fact that Station 8 remains separate from the group under all the ordination alternatives. Again, access to information detailing which species are most influential in producing the output is only available through the inspection of factors associated with the principal components analysis.

As mentioned earlier, an additional use of ordination techniques is in clarifying relations between station groups. The most obvious relationship is the constant close association between the nearshore and Bristol Bay groups (IG1, IG2, and IG3). This is most evident in Figures 12 and 21. MSG is generally closest to IG1, although under the principal components of the covariance matrix (Figure 16) ordering the relation between MSG and the other groups is difficult to discern.

OSG has already been described as somewhat diffuse. Under none of the ordination alternatives is OSG clearly affiliated with either MSG or the nearshore groups (IG1, IG2, IG3). Thus, an inshore/offshore polarity is indicated, with IG1, IG2, and IG3 being closely related and MSG less clearly allied to IG1.

BIOTIC AND ABIOTIC FACTORS AFFECTING COMMUNITY STRUCTURE

Differences in the trophic structure of the infaunal communities were seen between several of the station groups outlined by the numerical analysis. An increase in the ratio of abundances of suspension feeding organisms to those of other trophic levels from 0.18 to 0.45 (Table 10) was found in the offshore progression from IG1 to MSG. A subsequent decrease in this ratio, from 0.45 to 0.23 was found in moving from MSG to the outer shelf group, OSG.

The results of several benthic community studies have addressed the relationship between sediment characteristics and sedimentation rate to community structure. Rhoads and Young (1970) and Levinton (1977) reported the exclusion of suspension feeding organisms from certain areas of Buzzards Bay, Massachusetts. Their studies suggest that instability in silt/clay sediments facilitates tidal-current resuspension of sediments which in turn adversely affect suspension feeders by clogging filtering apparatus and burial of larval forms. Rhoads and Young (1970) indicate that a resuspension of sediments may also be effected by detrital feeders in the process of foraging.

Feder *et al.* (1978) have implicated sediments in the exclusion of suspension feeders in certain areas of continental shelf of the Gulf of Alaska and Prince William Sound, Alaska. These areas are subject to direct input of glacier-borne sediments from streams draining coastal glaciers and from the discharge of the Copper River. The resulting high sedimentation rates are thought to effectively limit suspension feeders, again by suffocation and burial. Thus, exceedingly high rates of sedimentation related to specific characteristics of the abiotic environment may result in adverse effects on suspension-feeding organisms. Such effects resemble closely those caused by the action of detrital-feeding communities on a coincident suspension-feeding community. It should be emphasized that in both Buzzards Bay and the Gulf of Alaska, silt/clay fractions are commonly higher than 50%, and the water content of the sediments is also high [over 50% in the first 2 cm (G. E. M. Matheke, pers. comm.)]. Although no data on water content of sediments is available for the Bering Sea study area, silt/clay fraction in the area of fine-particle deposition (OSG), averages only 40% (Table 11).

Sokolova (1959) has hypothesized that community structure on the slope and floor of the Kurile-Kamchatka Trench and the Bering Sea is largely determined by food supply, which is in turn linked to sedimentation rates. High sedimentation rates are thought necessary to ensure adequate food input to the detrital-feeding communities. High suspended loads are required to ensure the food source for suspension feeding communities. Sokolova was primarily interested in community structure from deep benthic environments. These are areas in which the very high sedimentation rates experienced in Prince William Sound and the high tidal current velocities found in Buzzards Bay are generally not found. High sediment rates and high bottom currents do not, in the work of Sokolova, refer to levels sufficiently high to adversely affect the suspension-feeding community.

Thus, community structure may be intimately related to overlying current structure, as it is the bottom currents that maintain the suspended load. It has been assumed that suspension feeders actively feed at varying heights in the water above the sea floor. Many may also actively feed on the detrital layer at the sediment surface if a food source superior to that of the water column may be reached. This occasional detrital feeding by suspension feeders will be limited by exhaustion of local food resources, especially for those suspension feeders that are sessile. Relocation on the part of motile or discreetly motile suspension feeders may be energetically unfavorable, especially if significant effort is required for the construction of tubes.

Jumars and Fauchald (1977) also suggest that food supply is related to community structure in the polychaete communities off the coast of southern California, but their observations deal more with the requirements of mobility to increase the extent of foraging areas as the organic carbon content of the sedimentary environment decreases. Their hypothesis did not deal directly with the problem of trophic structure since suspension feeders were never numerically important in their study areas.

In contrast to the theories outlined above, the observed changes in distributions of suspension feeders from IG1 to MSG seem, for several reasons, to be unrelated to sedimentation rates or sediment types. The compact sand bottom of IG1 should be conducive to the establishment of a suspension feeding community. Such sandy, compact sediments provide a firm substrate for the construction and placement of tubes, and should not resuspend easily. Also, the combined absence of coastal glaciers in this area and the advection of the Kuskokwim River outflow to the northern shelf area means that sedimentation rates in IG1 are probably not high enough to exclude suspension feeders.

One explanation for the observed paucity of suspension feeders in IG1 may be based on storm-wave induced turbulence. Sharma (1975) has calculated that bottom current velocities of approximately 30 cm/sec may commonly occur in water depths of 94 m in the Bering Sea. However, most stations of IG1 are at depth less than 50 m. Significant wave heights and periods of 6-7.5 m and 8-9 sec constitute 1% of all observed waves for this area in the month of November (Brower *et al.*, 1977). Further, waves of 8-9.5 m with significant periods of 13 sec have also been observed. Calculations of maximum bottom currents induced by such waves may be made as follows:

$$\mu_{max} = a\delta \frac{\cosh k(z+h)}{\sinh kh}$$

where a equals amplitude, δ equals $2\pi/T$, T equals period, k equals $2\pi/1$, z equals depth for which μ is being calculated (z is positive upward), and h equals bottom depth (McLellan, 1965). Maximum horizontal bottom current velocities corresponding to such waves would be approximately 24 cm/sec for the smaller wave and over 150 cm/sec for the larger (calculated for one meter above bottom, with a bottom depth of 50 m). Such high velocities could cause significant mortality among the suspension feeding community, especially on organisms attached to the sediment surface. Wave scour has been shown to inflict significant damage to benthic infaunal communities of the North Wales coast (Rees *et al.*, 1977), although the study concentrated on bottoms shallower than 15 m. Mortality, in this case, would be due to direct washing of organisms from the sediment surface, exposure of sediment-dwellers to predators, or possible burial of mature or larval forms. A detailed knowledge of the habits of these organisms and especially of their tolerance to disturbance is unavailable at this time.

The preceding discussion is highly speculative. The actual effects of wave-induced turbulence on benthic organisms is not well known. In addition, the magnitude of wave-induced turbulence in the area of IG1 is uncertain. Ice cover over much of the winter may effectively shield the bottom from the effects of winter storms. Such a shielding would result in a relatively undisturbed benthic environment. Rhoads *et al.* (1978) noted that slow-growing detrital feeding organisms are often characteristic of undisturbed bottoms, while fast-growing opportunists, many of which are suspension feeders, characterize environments subject to disturbance. If ice cover does shield the bottom in the area of IG1, then an impoverished suspension-feeding community might be expected. It seems unlikely, however, that the area covered by IG1 is well-shielded from winter storms, as the ice front is usually not far advanced by mid-November, the time for which the wave-induced bottom currents were calculated above.

The increase in the ratio of suspension feeders to other trophic types from 0.18 in IG1 to 0.45 in MSG may well be attributable to a damping of storm-wave-induced turbulence with depth. Another potential factor in this situation is seasonal productivity. As mentioned earlier, retreat of ice in the spring is followed by an intensive bloom. The algal populations are apparently not completely utilized by the zooplankton in the area and have been found to sink to within several meters of the bottom (Alexander, 1978; Taniguchi *et al.*, 1976). Although it is not likely that these populations continue to actively photosynthesize, they represent, while suspended just above the bottom, a potentially significant food resource for benthic suspension feeders. After sinking to the sediment surface, any remnants of the bloom will be accessible to both detrital feeders and some suspension feeders. The implication is that an adequate food source probably exists for the suspension feeding community; in addition, adverse effects of the presence of a detrital feeding community are not yet felt. Although the sediments from MSG are finer in size than those of IG1, they are still classified as fine sand and are compact enough to prevent easy resuspension. Thus, the type of amensalism noted by Rhoads and Young (1970) is not likely to occur in MSG. As noted above, Levinton (1977) reported disturbance of suspension feeding communities on bottom with greater than 50% silt/clay fractions, while the silt/clay fraction from the area of MSG is only 37%.

Uncertainties concerning the effect of turbulence in the area of MSG also exist. Many of the stations of this group are found at depths less than 70 m, for which substantial storm-induced turbulence may exist. Threshold levels for disturbance of this type need be known to assess the role of turbulence in such marginal situations.

The causes of reduction in abundance of suspension feeding individuals in OSG are probably related to the considerations outlined by Sokolova (1959). This area is not ice-covered in an average year, although at times the pack ice will extend into it. Thus, a direct introduction of primary productivity to the greater depths of the OSG stations is probably not a regular occurrence. Also, with increasing depth, the effect of storm-induced turbulence is negligible. Thus, the bottom community in this area is not subjected to the extreme events characteristic of station groups nearer to shore. Bering Sea source water enters outer Bristol Bay through this area, implying that current velocities strong enough to keep some material suspended do exist. Sediments from this region clearly show a higher percentage of fine particles than do sediments from other areas included in the major station groups. However, OSG sediments are still coarser than those from study areas in Quisset Harbor, Massachusetts, in which elimination of suspension feeders has been linked to the action of detrital feeders (Levinton, 1977). It seems, then, that neither the detrital feeding nor suspension feeding mode should be clearly favored, a prediction substantiated by the ratio of 0.24.

Several hypotheses concerning the near absence of suspension feeders from IG2 are forthcoming on the basis of sediment information. Sediments from this group are primarily gravel and coarse sand. This condition may result from the presence of substantial currents in the overlying water. Myers (1976) has proposed an Eckman-related upwelling scheme which may explain the existence of locally high currents in the Bristol Bay area. Also, the proximity of these stations to the Alaska Peninsula may result in a high gravel content since this region is tectonically active. The exceedingly high sand/gravel fraction coupled with periodic high bottom currents could result in unstable bottom conditions that are not favorable to the maintenance of a suspension feeding community.

An analysis of the underlying causes of the distribution of species groups is beyond the scope of this study. Research on the part of Russian workers has covered both trophic classification and zoogeographic affinities of the organisms in this area. Semenov (1968) concluded that, along a transect extending out of Bristol Bay, changes in the infaunal communities were related to both temperature and food availability. Predominance of certain trophic groups was found to coincide with changes in zoogeographic complexes, and both effects were attributed to characteristics of the overlying water masses. Neiman (1963) outlined a similar relationship. Her work covered a larger area (the entire eastern Bering Sea shelf and continental slope), and did not detail community structure in much of the area under consideration in the present study. The dominance zones of zoogeographic complexes delineated by Semenov (1968) are in agreement with the distributions of the three water masses previously described for this area. The water mass distributions also coincide with the inshore/offshore trends in species composition and trophic structure suggested by this study. While much work remains to be done on the effect of turbulence, food availability and temperature, it seems likely that these parameters will ultimately be found the most important in determining the structure of benthic communities in this area.

SUMMARY

The combined use of the techniques of cluster analysis, principal components, and principal coordinates analysis led to several conclusions concerning the existence of biological provinces and species assemblages in the study area.

1) Five major station groups were found to encompass 47 of the 62 stations under study. Three main groups account for 39 of these stations. These three groups occupy adjacent bands whose long axis roughly parallels the bathymetry, defining contiguous areas of increasing depth. Two smaller groups (4 stations each) are found in the vicinity of the head of Bristol Bay and around Nunivak Island.

2) Fifty-six species assemblages have also been delineated. The distribution of thirteen of these show strong correlations with the major station groups. Two broad classes of the species groups are obvious: (a) those with distributions generally confined to a single station group, and (b) those considered ubiquitous but showing marked changes in numbers at the different station groups.

Several ecological differences between the main station groups are evident.

(a) An inshore/offshore polarity exists, with high numbers of individuals being found in the coarse sand bottoms of the inshore areas and progressively lower abundances in the finer sediments of the offshore areas (MSG and OSG).

(b) An increase in the ratio of suspension-feeding organisms to other trophic types was seen in the midshelf area. The ratio was 0.45 in MSG, 0.18 in IG1, and 0.24 in OSG. The differences between groups is thought to be based on a difference in food supply and differences in the effect of storm-wave-induced turbulence on the shallow-dwelling suspension feeding community.

(c) A near absence of suspension feeding individuals in the coarse sand and gravel areas at the head of Bristol Bay (IG2).

(d) A low diversity in the midshelf area (MSG) when compared to both the inner and outer shelf groups (IG1 and OSG). In the former case, high diversity stems from the large number of individuals present, while in the latter case it results from high species richness (i.e., high numbers of species found at each station).

LITERATURE CITED

Alexander, V. 1978. Environmental assessment of the Alaskan continental shelf. Annual Report to NOAA. RU #427. 246 pp.

Alton, M. S. 1974. Bering Sea benthos as a food resource for demersal fish populations. Pages 257-279 *In* D. W. Hood and E. J. Kelley, eds., *Oceanography of the Bering Sea with emphasis on renewable resources*. Institute of Marine Science, University of Alaska, Fairbanks, Alaska. 623 pp.

Anderberg, M. R. 1973. Cluster analysis for applications. Academic Press, New York. 359 pp.

Blackith, R. E. and R. A. Reyment. 1971. Multivariate morphometrics. Academic Press, New York. 412 pp.

Brower, W. A., Jr., H. F. Diaz and A. S. Prechtel. 1977. Climatic atlas of the outer continental shelf waters and coastal regions of Alaska. Vol. II--Bering Sea. Arctic Environmental Information and Data Center, Anchorage, Alaska. 443 pp.

Chardy, P., M. Glemarec and A. Laurec. 1976. Applications of inertia methods to benthic marine ecology: practical implications of the basic options. *Estuarine and Coastal Marine Science* 4(2):179-205.

Clifford, H. T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York. 229 pp.

Coachman, L. K. and R. L. Charnell. 1977. Finestructure in outer Bristol Bay, Alaska. *Deep Sea Research* 24(10):869-889.

Feder, H. M. and G. E. M. Matheke. 1978. The distribution, abundance, community structure, and trophic relations of the benthos of the northeastern Gulf of Alaska. Final Report to NOAA. Institute of Marine Science, University of Alaska, Fairbanks, Alaska. (In prep.)

Field, J. G. 1970. The use of numerical methods to determine benthic distribution patterns from dredging in False Bay. Transactions of the Royal Society of South Africa 39(2):183-200.

Gower, J. C. 1966. Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika* 53(3):325-338.

_____. 1967. Multivariate analysis and multidimensional geometry. *Statistician* 17(1):13-28.

_____. 1969. A comparison of some methods of cluster analysis. *Biometrics* 23:623-637.

Hartigan, J. A. 1975. Clustering algorithms. John Wiley and Sons, New York. 351 pp.

Hoskin, C. M. 1978. Benthos-sedimentary substrate interactions. Principal investigators Final Report to NOAA. RU #291/292. (In prep.)

Hotelling, H. 1933. Analysis of a complex of statistical variables into principal components. *Journal of Educational Psychology* 24:417-441, 498-520.

Jumars, P. A. and K. Fauchald. 1977. Between-community contrasts in successful polychaete feeding strategies. Pages 1-21 *In* Bruce C. Coull, ed., *Ecology of the marine benthos*. University of South Carolina Press. 467 pp.

Levinton, J. S. 1977. Ecology of shallow water deposit-feeding communities. Pages 191-229 *In* Bruce C. Coull, ed., *Ecology of the marine benthos*. University of South Carolina Press. 467 pp.

Lie, U. and D. S. Kisker. 1970. Species composition and structure of benthic infauna communities off the coast of Washington. *Journal of the Fisheries Research Board of Canada* 27(III):2273-2285.

Margalef, R. D. 1968. Perspectives in Ecological Theory. University of Chicago Press. 111 pp.

Matheke, G. E. M., H. M. Feder and G. Mueller. 1976. Numerical analysis of the benthic infauna in the northeastern Gulf of Alaska. *In* D. N. Norton, ed., *Proceedings of the 27th Alaska Science Conference, Vol.II*.

McConnaughey, B. H. 1964. The determination and analysis of plankton communities. Marine Research of Indonesia Spec. 1-40 pp.

McLellan, H. J. 1965. Elements of physical oceanography. Pergamon Press, Edinburgh. 151 pp.

McRoy, C. P. and J. J. Goering. 1972. The influence of ice on the primary productivity of the Bering Sea. Pages 403-425 *In* D. W. Hood and E. J. Kelley, eds., *Oceanography of the Bering Sea and adjacent regions with emphasis on renewable resources*. Institute of Marine Science, University of Alaska, Fairbanks, Alaska. 623 pp.

Morrison, D. F. 1975. Multivariate statistical methods. McGraw-Hill, New York. 415 pp.

Myers, R. L. 1976. On the physical oceanography of Bristol Bay: 1969-1970. Unpublished MS Thesis. Institute of Marine Science, University of Alaska, Fairbanks, Alaska. 83 pp.

Neiman, A. A. 1963. Quantitative distribution of benthos on the shelf and upper continental slope in the eastern part of the Bering Sea. Pages 143-217 *In Soviet fisheries investigations in the northeast Pacific, Part I.* (Transl. from Russian). Israel Program for Scientific Translations, 1968).

Orloci, L. 1966. Geometric models in ecology: the theory and application of some ordination methods. *Journal of Ecology* 54(1):193-215.

______. 1967. Data centering: a review and evaluation with references to component analysis. *Systematic Zoology* 16(3):208-212.

Pearson, K. 1901. On lines and planes of closest fit to systems of points in space. *Philosophical Magazine* 6(2):559-572.

Peterson, C. G. 1913. Valuation of the sea. II. The animal communities of the sea bottom and their importance for marine zoogeography. Reprint of the Danish Biological Station 23:1-42.

Pielou, E. C. 1977. Mathematical ecology. John Wiley and Sons, New York. 385 pp.

Rees, E. I. S., A. Nicholaidou and P. Laskaridou. 1977. The effects of storms on the dynamics of shallow water benthic associations. Pages 465-473 *In* B. F. Keegen, P. O. Ceidigh and P. J. S. Boadan, eds., European Marine Biology Symposia, 11th, Galway, Ireland, 1976. *Biology of Benthic Organisms.* Pergamon Press, New York. 630 pp.

Rhoads, D. C., P. L. McCalland and J. Y. Yingst. 1978. Disturbance and production on the estuarine seafloor. *American Scientist* 66(5):577-587.

Rhoads, D. C. and D. K. Young. 1970. The influence of deposit-feeding organisms on sediment stability and community structure. *Journal of Marine Research* 28(2):150-178.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. *American Naturalist* 102(925):243-282.

Semenov, V. N. 1968. Quantitative distribution of benthos on the shelf of the southeastern Bering Sea. Pages 2167-2175 *In Soviet fisheries investigations in the northeast Pacific, Part I.* (Transl. from Russian). Israel Program for Scientific Translations, 1968.

Sharma, G. D. 1974. Contemporary depositional environment of the eastern Bering Sea. Part 1. Contemporary sedimentary regimes of the eastern Bering Sea. Pages 517-541 *In* D. W. Hood and E. J. Kelley, eds., *Oceanography of the Bering Sea with emphasis on renewable resources.* Institute of Marine Science, University of Alaska, Fairbanks, Alaska. 623 pp.

Sharma, G. D. 1975. Contemporary epicontinental shelf grading in the southeast Bering Sea. Pages 38-48 *In* R. B. Forbes, ed., *Contributions to the geology of the Bering Sea basin and adjacent regions*. Geological Society of America Special Paper 161. 214 pp.

Sharma, G. D., A. S. Naidu and D. W. Hood. 1972. Bristol Bay: A model contemporary graded shelf. American Association of Petroleum Geologists Bulletin 56(10):2000-2012.

Sokolova, M. N. 1959. On the distribution of deep-water bottom animals in relation to their feeding habits and character of sedimentation. *Deep Sea Research* 6(1):1-4.

Stephenson, W. 1973. The use of computers in classifying marine bottom communities. Pages 463-473 *In* R. Fraser, comp., *Oceanography of the South Pacific 1972*. New Zealand National Commission for UNESCO, Wellington.

Stephenson, W., W. T. Williams and G. N. Lance. 1970. The macrobenthos of Moreton Bay. *Ecological Monographs* 40(4):459-494.

Stoker, S. W. 1973. Winter studies of under-ice benthos on the continental shelf of the Bering Sea. Unpublished MS Thesis, University of Alaska, Fairbanks, Alaska. 60 pp.

______. 1978. Benthic macrofauna of the Bering/Chukchi Sea shelf. Ph.D Dissertation. Institute of Marine Science, University of Alaska, Fairbanks, Alaska.

Takenouti, A. Y. and K. Ohtani. 1974. Currents and water masses in the Bering Sea. Pages 403-425 *In* D. W. Hood and E. J. Kelley, eds., *Oceanography of the Bering Sea with emphasis on renewable resources*. Institute of Marine Science, University of Alaska, Fairbanks, Alaska. 623 pp.

Taniguchi, A., S. Kazutoshi, K. Akio and F. Mitsuo. 1976. Phytoplankton communities in the Bering Sea and adjacent seas. I. Communities in early warming season in southern areas. *Journal of Oceanographic Society of Japan* 32:99-106.

Thorson, G. 1957. Marine level-bottom communities (sublittoral or shallow shelf). Chapter 17 *In* Geological Society of America Memoir 67(1):461-534.

Williams, W. T. and J. M. Lambert. 1961. Multi-variate methods in plant ecology. II: Inverse association analysis. *Journal of Ecology* 49(3):717-729.

Williams, W. T. and G. N. Lance. 1977. Hierarchial classificatory methods. Pages 269-295 *In* C. Enslein, A. Ralston and H. S. Wils, eds., *Statistical methods for digital computers*. (Volume III of Mathematical Methods for Digital Computers). Wiley Interscience Publications, New York. 454 pp.

Williams, W. T. and W. Stephenson. 1973. The analysis of three-dimensional data (sites × species × times) in marine ecology. *Journal of Experimental Marine Biology and Ecology* 11:207-227.

APPENDIX I. Station location, sampling date, and depth of stations used in Bering Sea infaunal studies.

Station	Latitude	Longitude	Date Sampled	Depth (m)
1	55°18'	163°18'	7 June 75	47
2	55°51'	162°17'	7 June 75	43
3	56°17'	161°02'	8 June 75	52
4	56°46'	159°52'	8 June 75	52
5	57°21'	158°58'	8 June 75	45
6	47°43'	159°05'	8 June 75	47
7	57°58'	158°15'	8 June 75	35
8	58°17'	159°32'	8 June 75	24
9	57°55'	160°08'	9 June 75	53
10	57°19'	161°06'	9 June 75	65
11	56°45'	161°59'	9 June 75	71
12	56°09'	162°56'	9 June 75	83
13	55°33'	163°49'	7 June 75	67
14	54°39'	165°25'	7 June 75	165
15	54°18'	167°36'	29 May 75	1,006
16	54°53'	166°44'	28 May 75	205
17	65°29'	165°50'	28 May 75	121
18	56°06'	164°54'	28 May 75	95
19	56°40'	163°57'	10 June 75	77
20	57°15'	163°05'	10 June 75	54
22	57°50'	162°11'	10 June 75	45
23	58°20'	161°21'	10 June 75	31
24	58°46'	162°29'	10 June 75	73
25	58°19'	163°13'	11 June 75	35
27	57°40'	164°16'	11 June 75	53
28	57°10'	165°04'	11 June 75	70
29	56°36'	165°57'	28 May 75	84
30	56°00'	166°51'	27 May 75	133
31	55°22'	167°47'	6 June 75	165
35	56°13'	168°20'	5 June 75	163
36	56°31'	167°55'	27 May 75	117
37	58°40'	169°00'	16 June 75	75
38	57°40'	166°06'	11 June 75	66
39	58°03'	165°29'	11 June 75	51
40	58°08'	165°16'	12 June 75	47
41	58°47'	164°15'	12 June 75	34
42	59°16'	165°20'	12 June 75	22
43	58°42'	166°17'	12 June 75	38
45	58°10'	167°10'	12 June 75	67
47	56°58'	169°01'	18 August 75	84
49	56°25'	169°56'	4 June 75	110
55	57°29'	170°08'	20 August 75	73
57	58°36'	168°13'	13 June 75	53
59	59°12'	167°18'	13 June 75	38
60	59°43'	166°24'	13 June 75	24

APPENDIX I. Continued

Station	Latitude	Longitude	Date Sampled	Depth (m)
61	59°39'	168°22'	13 June 75	39
62	59°06'	169°15'	13 June 75	53
63	58°33'	170°10'	14 June 75	73
64	58°01'	171°08'	14 June 75	90
65	57°25'	172°05'	14 June 75	105
70	58°29'	172°11'	21 August 75	106
71	59°04'	171°10'	21 August 75	82
72	59°34'	170°19'	24 August 75	68
73	60°02'	169°29'	23 August 75	48
82	60°33'	170°29'	22 August 75	60
83	60°02'	171°26'	23 August 75	73
924	57°28'	167°28'	22 May 75	73
935	58°50'	169°19'	24 May 75	68
937	58°41'	169°18'	25 May 75	65
939	58°29'	169°19'	25 May 75	71
941	58°20'	169°19'	25 May 75	70
942	58°28'	169°23'	25 May 75	70

APPENDIX II. Sample data sheet from Bering Sea infaunal studies.
Bering Sea Benthos -- *Discoverer* Cruise 808, Station 007, June 8, 1975.

		Percents refer to total collections at this station					
	Sample	Count		Wet Weight		Per Sq. Meter	
Taxon Name	No.	No.	Pct	Grams	Pct	No.	Wet wt.
Rhynchocoela	3	1	0.63	0.001	0.00	1	0.001
Nematoda	4	1	0.63	0.001	0.00	1	0.001
Polychaeta	4	1	0.63	0.002	0.01	1	0.003
Anaitides mucosa	6	1	0.63	0.009	0.05	1	0.013
Eteone lonca	4	1	0.63	0.000	0.00	1	0.001
Mephtys caeca	3	1	0.63	0.146	0.79	1	0.208
Haploscoloplos panamensis	2	4	2.52	0.007	0.04	6	0.010
Haploscoloplos panamensis	4	2	1.26	0.004	0.02	3	0.006
Haploscoloplos panamensis	3	3	1.89	0.009	0.05	4	0.013
Haploscoloplos panamensis	6	4	2.52	0.008	0.04	6	0.011
Subtotal		13	8.18	0.028	0.15	19	0.040
Spiophanes cirrata	2	1	0.63	0.000	0.00	1	0.000
Ophelia limacina	2	14	8.81	0.170	0.92	20	0.244
Ophelia limacina	7	1	0.63	0.	0.	1	0.
Ophelia limacina	5	2	1.26	0.010	0.06	3	0.015
Ophelia limacina	3	1	0.63	0.002	0.01	1	0.002
Ophelia limacina	4	1	0.63	0.011	0.06	1	0.016
Ophelia limacina	6	1	0.63	0.002	0.01	1	0.002
Subtotal		20	12.58	0.195	1.05	29	0.279
Travisia forbesii	4	1	0.63	0.008	0.04	1	0.011
Travisia forbesii	6	5	3.14	0.037	0.20	7	0.053
Travisia forbesii	2	2	1.26	0.035	0.19	3	0.050
Subtotal		8	5.03	0.080	0.43	11	0.115

APPENDIX II. Continued

		Percents refer to total collections at this station					
	Sample	Count		Wet Weight		Per Sq. Meter	
Taxon Name	No.	No.	Pct	Grams	Pct	No.	Wet wt.
Polycirrus medusa	3	1	0.63	0.004	0.02	1	0.006
Sabella sp.	5	1	0.63	0.000	0.00	1	0.000
Mollusca	4	1	0.63	0.001	0.01	1	0.002
Macoma balthica	5	1	0.63	0.004	0.02	1	0.005
Macoma balthica	4	1	0.63	0.001	0.01	1	0.002
Subtotal		2	1.26	0.005	0.03	3	0.007
Tellina lutea alternidentata	6	1	0.63	1.119	6.04	1	1.599
Tellina lutea alternidentata	3	2	1.26	2.959	15.96	3	4.228
Tellina lutea alternidentata	2	1	0.63	0.252	1.36	1	0.359
Subtotal		4	2.52	4.330	23.35	6	6.186
Solariella obscura	3	1	0.63	0.010	0.05	1	0.014
Solariella obscura	6	1	0.63	0.006	0.03	1	0.008
Subtotal		2	1.26	0.015	0.08	3	0.022
Maustoriidae equs	3	1	0.63	0.	0.	1	0.
Anomyx nugax	3	1	0.63	0.065	0.35	1	0.093
Monoculodes zernovi	2	1	0.63	0.001	0.00	1	0.001
Monoculodes zernovi	6	1	0.63	0.005	0.02	1	0.007
Subtotal		2	1.26	0.005	0.03	3	0.008
Monoculodes mertensi	2	1	0.63	0.001	0.00	1	0.001
Paraphoxus sp.	2	2	1.26	0.007	0.04	3	0.010
Paraphoxus sp.	6	1	0.63	0.020	0.11	1	0.028
Paraphoxus sp.	5	1	0.63	0.004	0.02	1	0.006
Paraphoxus sp.	3	4	2.52	0.	0.	6	0.
Paraphoxus sp.	4	3	1.89	0.006	0.03	4	0.009
Subtotal		11	6.92	0.037	0.20	16	0.053

APPENDIX II. Continued

Taxon Name	Sample No.	Count No.	Count Pct	Wet Weight Grams	Wet Weight Pct	Per Sq. Meter No.	Per Sq. Meter Wet wt.
		Percents refer to total collections at this station					
Decapoda	2	1	0.63	0.000	0.00	1	0.000
Crangon alaskensis	4	1	0.63	0.033	0.18	1	0.047
Crangon alaskensis	5	1	0.63	0.049	0.26	1	0.070
Crangon alaskensis	6	1	0.63	0.292	1.57	1	0.417
Subtotal		3	1.89	0.373	2.01	4	0.533
Ectoprocta	4	1	0.63	0.000	0.00	1	0.000
Ectoprocta	5	1	0.63	0.013	0.07	1	0.018
Subtotal		2	1.26	0.013	0.07	3	0.018
Echinarachnius parma	5	12	7.55	4.403	23.75	17	6.291
Echinarachnius parma	4	27	16.98	7.617	41.08	39	10.882
Echinarachnius parma	6	5	3.14	0.022	0.12	7	0.031
Echinarachnius parma	2	12	7.55	1.091	5.88	17	1.559
Echinarachnius parma	7	15	9.43	0.	0.	21	0.
Echinarachnius parma	3	6	3.77	0.079	0.42	9	0.112
Echinarachnius parma	1	1	0.63	0.018	0.10	1	0.026
Subtotal		78	49.06	13.230	71.35	111	18.900
Station Total		159		18.544		227	26.491

APPENDIX III. Species used in classification of Bering Sea benthic stations infaunal studies.

Polychaeta

Gattyana treadwelli
Harmothoe imbricata
Polynof canadensis
Peisidice aspera
Phloe minuta
Anaitides groenlandica
Anaitides mucosa
Anaitides maculata
Eteone spetsbergensis
Eteone longa
Nephtys ciliata
Nephtys caeca
Nephtys punctata
Nephtys rickettsi
Nephtys longasetosa
Aglaophamus rubilla anops
Glycera capitata
Glycinde picta
Glycinde armigera
Onuphis geophiliformis
Eunice valens
Lumbrinereis similabris
Lumbrinereis zonata
Ninve gemmea
Drilonereis falcata minor
Haploscoloplos panamensis
Haploscoloplos elongatus
Scoloplos armiger
Aricidea suecica
Aricidea uschakowi
Paraonis gracilis
Laonice cirrata
Polydora socialis
Polydora concharum
Prionospio malmgreni
Spio filicornis
Spiophanes bombyx
Spiophanes kroyeri
Spiophanes cirrata
Magelona japonica
Magelona pacifica

Polychaeta (cont.)

Tharyx sp.
Chaetozone setosa
Brada villosa
Scalibregma inflatum
Ammotrypane aulogaster
Ophelia limacina
Travisia brevis
Travisia forbesii
Sternaspis scutata
Capitella capitata
Heteromastus filiformis
Maldane sarsi
Maldane glebifex
Nicomache personata
Notoproctus pacifica
Praxillella gracilis
Praxillella praetermissa
Rhodine loveni
Owenia fusiformis
Myriochele heeri
Cistenides brevicoma
Cistenides granulata
Cistenides hyperborea
Ampharete arctica
Ampharete acutifrons
Lysippe labiata
Pista cristata
Pista maculata
Artacama proboscidea
Laphanis boecki
Proclea emmi
Terebellides stroemii
Chone gracilis
Chone infundibuliformis
Chone cincta
Chone duneri
Euchone analis
Pseudopotamilla reniformis
Cossura longocirrata

Mollusca

Acila castrenis
Nucula tenuis
Nuculana pernula
Yoldia amygdaiea

Arthropoda

Balanus crenatus
Balanus hesperius
Balanus rostratus
Leucon nasica

APPENDIX III. Continued

Mollusca (cont.)

Yoldia hyperborea
Yoldia scissurata
Yoldia secunda
Dacrydium pacificum
Modiolus modiolus
Astarte polaris
Astarte esquimaulti
Cyclocardia ventricoa
Cyclocardia crebricostata
Cyclocardia crassidens
Axinopsida serricata
Thyasira flexuosa
Mysella tumida
Mysella aleutica
Odontogena borealis
Clinocardium ciliatum
Serripes groenlandicus
Psephidia lordi
Spisula polynyma
Macoma calcarea
Macoma brota
Macoma moesta alaskana
Macoma lama
Tellina lutea alternidentata
Lyonsia norvegica
Margarites olivaceus
Solariella obscura
Solariella varicosa
Tachyrynchus erosus
Polinices nanus
Polinices pallida
Neptunea ventricosa
Neptunea heros
Admete couthouyi
Retusa obtusa
Cylichna occulta
Cylichna alba

Echinodermata

Asterias amurensis
Dendraster excentricus
Echinarachnius parma
Amphipholis pugetana
Diamphiodia craterodmeta
Ophiura sarsi
Cucumaria calcigera
Psolus phantapus

Arthropoda (cont.)

Eudorella emarginata
Eudorella pacifica
Eudorellopsis integra
Eudorellopsis deformis
Diastylis alaskensis
Diastylis bidentata
Diastylis cf. *D. tetradon*
Ampelisca macrocephala
Ampeliscidae birulai
Ampeliscida eschrichti
Ampeliscida furcigera
Byblis gaimandi
Argissa hamatipes
Corophium crassicorne
Ericthonius hunteri
Melita dentata
Melita formosa
Euhaustorias eous
Pontoporeia femorata
Urothoe denticulata
Haustorious eous
Photis spasskii
Photis ninogradovi
Protomedeia fascata
Protomedeia grandimana
Protomedia fasciatoides
Protomedia chaelata
Anonyx nugax
Hippomedon kurilious
Orchomene nugux
Orchomene lepidula
Bathymedon nanseni
Monoculodes zernovi
Westwoodilla caecula
Harpinia kobjakovae
Harpinia gurjanovae
Harpina tarasovi
Paraphoxus simplex
Paraphoxus milleri
Paraphoxus obtusidens
Thysanoessa raschii

APPENDIX III. Continued

Sipunculida

- *Golfingia margaritacea*
- *Phascolion strombi*

Priapulida

- *Priapulus caudatus*

Brachiopoda

- *Terebratalia crossei*

Urochordata

- *Boltenia ovifera*
- *Boltenia villosa*

APPENDIX IV. Mathematical operations used in cluster analysis, principal components analysis, and principal coordinates analysis.

For the purposes of this appendix, it will be assumed that data has been gathered for n species from m stations. The data will be contained in the matrix X where x_{ij} represents the number of the ith species found at the jth station. The n rows of this matrix then represent species while the m columns represent stations.

Part 1. Cluster Analysis.

Given the matrix X, a distance matrix S is constructed such that s_{ij} represents the distance between stations i and j (normal analysis) or species i and j (inverse analysis). The Czekanowski and Canberra metric dissimilarity coefficients were used as distance measures in the normal analysis while only the Czekanowski measure was used in the inverse analysis.

Normal analysis:

Czekanowski coefficient

$$s_{ij} = \frac{\sum_{e=1}^{m} |(x_{ei}-x_{ej})|}{\sum_{e=1}^{n} (x_{ei}+x_{ej})} \tag{1}$$

Canberra metric coefficient

$$s_{ij} = \sum_{e=1}^{m} \frac{|x_{ei}-x_{ej}|}{(x_{ei}+x_{ej})} \tag{2}$$

In the normal analysis, S is m×m and symmetric.

Inverse analysis:

$$s_{ij} = \frac{\sum_{e=1}^{n} |x_{ie}-x_{je}|}{\sum_{e=1}^{n} (x_{ie}+x_{je})} \tag{3}$$

In the inverse analysis, S is n n and symmetric.

The cluster analysis proceeds by joining entities of the matrix S (since S is symmetric, rows and columns represent the same entity). This is accomplished by finding the smallest element in S (corresponding to the smallest distance between entities) and joining these elements. Distance between the newly formed entity and all remaining individuals or entities must be recalculated according to the general formula:

$$d_{hk} = \alpha_i d_{hi} + \alpha_j d_{hj} + \beta d_{ij} + \gamma |d_{hi} - d_{hj}| \qquad (4)$$

Entities i and j have been fused and renamed "k"; d_{hk} is the new distance between cluster k and some previously existing cluster, h. The recalculated distances are substituted for the row (considering only the lower triangle of S, since it is symmetric) entries in S corresponding to one of the fused elements. The row corresponding to the other fused element is removed and the dimension of S are effectively reduced by 1×1 after each fusion procedure.

The specific values of parameters of the update equation (equation 4) used in this study are:

Nearest neighbor strategy

$$(\alpha_i = \alpha_j = +0.5, \beta = 0, \gamma = -0.5) \qquad (5)$$

Group average strategy

$$(\alpha_i = n_i/n_k, \alpha_j = n_j/n_k, \beta = \gamma = 0.0) \qquad (6)$$

Flexible sorting strategy

$$(\alpha_i + \alpha_j + \beta = 1.0, \alpha_i = \alpha_j, \beta<1.0, \gamma = 0.0) \qquad (7)$$

[see Lance and Williams (1977) and Anderberg (1973)].

Part 2. Principal Components Analysis.

Slightly different procedures are followed to calculate the variants of principal components analysis used in this study. These variants are the principal components analysis based on the covariance matrix and the principal components analysis based on the correlation matrix.

Given the matrix X, row centering to produce the matrix A is accomplished as follows:

$$\text{Covariance matrix} \qquad a_{ij} = \frac{x_{ij} - \bar{x}_i}{\sqrt{m-1}} \tag{8}$$

$$\text{Correlation matrix} . \quad a_{ij} = \frac{x_{ij} - \bar{x}_i}{\sum_{e=1}^{m} (x_{ie} - \bar{x}_i)^2} \tag{9}$$

where a_{ij} is an element of the matrix A and $\bar{x}_i$ equals the row mean:

$$\bar{x}_i = \sum_{e=1}^{m} x_{ie} \; / \; m \tag{10}$$

A is thus m×m.

The matrix Q is then formed by:

$$Q = A'A \tag{11}$$

where A' represents the transpose of A.

The eigenvalues and eigenvectors of Q are then found. The vector of station projections on the ith axis (component scores on the ith principal component) are found as y_i, where

$$y_i = \alpha_i \tag{12}$$

is the ith eigenvector of Q adjusted such that

$$\alpha_i' \, \alpha_i = \gamma_i \tag{13}$$

where γ_i is the ith eigenvalue of Q (see Orloci, 1967).

Part 3. Principal Coordinates Analysis.

Given the matrix X, the distance matrix S is calculated as in cluster analysis (Part 1, this appendix). S is then transformed to the matrix Q according to the following equation:

$$q_{ij} = s_{ij} - \bar{s}_i - \bar{s}_j + \bar{s} \tag{14}$$

where $\bar{s}_j$ is the mean of the ith row or column of S (S is m×m and symmetric):

$$\bar{s}_i = \frac{\sum_{i=1}^{m} s_{ij}}{m} \qquad (15)$$

and $\bar{s}$ is the overall mean:

$$\bar{s} = \frac{\sum_{j=1}^{m} \sum_{i=1}^{m} s_{ij}}{m} \qquad (16)$$

The vector of projections of the m stations (represented by rows or columns of the matrix S) onto the principal axes is found as y_i where

$$y_i = \delta_i \qquad (17)$$

and δ_i is the ith eigenvector of Q scaled such that

$$\delta_i{}'\delta_i = \gamma_i \qquad (18)$$

where γ_i is the ith eigenvalue of the matrix Q (see Gower, 1966).

APPENDIX V. Matrix of average cell densities. Cells are composed of station groups or unclassified stations and species groups as indicated by cluster analysis.

$$\text{Density} = \frac{\sum_{i=1}^{s}\sum_{j=1}^{n} x_{ij}}{ns}$$ where n = number of stations in cell, s = number of species in cell, x_{ij} = number of individuals of the ith cell species found at the jth cell station.*

Special Group	MSG	30,49	64,70	OSG	IG3	47,55	IG1	4	24	14	35	15	IG2	2	81,82
1	-	-	-	-	0.1	-	-	-	-	5.0	-	-	-	-	-
2	0.4	-	0.8	0.7	0.2	-	0.2	-	-	5.0	-	-	-	-	-
3	0.1	-	-	-	2.8	1.3	-	-	-	0.7	-	-	-	-	-
4	0.6	3.3	-	0.1	33.7	-	1.2	-	-	15.0	-	-	1.5	-	1.8
5	0.1	-	-	0.1	1.2	1.0	0.6	-	-	12.0	1.0	-	0.4	-	-
6	52.9	-	-	0.3	1.3	1.0	0.1	-	-	-	10.0	-	-	-	-
7	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
8	0.1	-	-	6.2	0.1	-	0.1	-	0.3	3.2	4.8	0.2	-	1.0	-
9	-	-	-	-	-	-	-	-	-	-	2.0	-	-	-	-
10	-	-	-	0.3	0.2	-	-	-	-	2.4	70.0	0.4	-	-	0.2
11	0.6	-	-	1.8	0.4	-	0.2	-	-	-	-	-	-	-	-
12	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-
13	0.2	-	-	0.9	1.4	-	-	-	-	-	-	-	-	-	-
14	8.0	-	-	0.1	-	1.0	-	-	5.0	1.0	-	-	-	-	-
15	0.1	-	1.0	4.3	-	-	-	-	-	-	-	-	-	-	-
16	0.1	-	-	0.4	0.3	0.5	1.2	-	-	1.0	-	-	-	-	-
17	0.7	-	-	-	0.2	-	0.9	-	2.5	-	-	-	13.8	-	-
18	2.3	-	-	-	0.5	-	0.9	-	-	-	-	-	-	-	-
19	-	-	-	0.4	0.2	-	22.8	-	-	-	-	-	0.2	-	-
20	0.6	-	-	0.1	-	-	0.8	3.3	-	-	-	-	-	-	-
21	1.4	-	-	0.9	0.3	2.0	1.2	-	-	-	-	-	-	-	-
22	0.5	-	-	0.3	-	-	-	-	-	-	-	-	-	-	1.0
23	0.9	-	-	1.6	-	1.0	1.4	-	2.5	-	-	-	-	-	2.5
24	10.2	-	1.1	10.1	0.2	1.7	0.8	-	-	-	-	-	-	-	13.7
25	40.1	9.2	6.6	14.6	4.3	16.9	26.0	3.6	65.7	2.4	1.9	2.1	0.3	2.2	3.3
26	11.6	1.5	33.5	5.2	0.6	5.4	2.2	-	2.0	-	0.4	1.2	-	-	8.2

APPENDIX V. Continued

Special Group	MSG	30,49	64,70	OSG	IG3	47,55	IG1	4	24	14	35	15	IG2	2	81,82
27	3.9	0.1	0.7	0.6	0.2	0.3	0.3	-	2.9	0.3	0.3	2.6	0.3	3.8	11.3
28	45.5	15.2	35.5	26.0	2.7	18.1	10.9	-	0.3	1.8	6.9	0.9	0.1	-	92.7
29	-	10.5	-	7.6	-	0.5	0.4	5.0	-	-	4.0	-	-	-	-
30	6.3	6.4	34.2	42.7	0.3	31.0	0.3	-	5.2	0.9	2.4	9.1	-	-	1.2
31	1.4	-	-	0.2	0.2	179.3	0.4	-	-	-	-	-	-	-	-
32	1.7	-	-	0.2	2.0	7.7	5.3	-	-	-	0.7	0.7	-	-	0.3
33	-	-	-	0.4	0.3	3.0	0.1	-	-	-	-	-	0.5	26.7	-
34	-	-	-	0.1	0.2	0.5	0.5	61.0	116.3	2.0	1.0	1.0	-	3.3	-
35	2.8	-	-	1.4	0.3	-	1.5	13.3	16.3	-	8.0	-	-	-	0.5
36	0.7	-	-	0.7	4.4	3.0	7.3	-	22.5	0.7	20.7	-	-	-	-
37	0.2	-	0.5	0.6	1.2	1.8	1.9	2.5	1.3	-	-	2.0	-	-	-
38	1.3	-	-	-	-	4.0	14.6	-	-	-	-	-	0.2	-	-
39	20.2	-	0.2	0.3	3.3	9.1	29.1	1.5	2.2	0.2	0.7	0.7	8.0	1.9	-
40	2.8	4.5	1.1	7.4	13.3	17.1	30.4	4.8	12.7	1.1	2.3	1.0	12.3	0.4	0.3
41	0.1	-	128.0	-	36.7	39.0	3.6	-	-	-	-	-	-	-	-
42	0.6	-	-	-	38.2	-	38.2	-	-	-	-	-	-	-	-
43	0.1	-	-	1.6	0.8	-	0.1	-	-	-	-	18.0	0.2	-	-
44	-	21.3	-	0.1	0.5	-	0.7	-	-	-	-	1.0	-	-	-
45	1.7	-	7.0	-	-	-	0.1	-	-	-	-	-	-	-	-
46	-	1.5	34.3	2.7	-	0.5	1.1	-	-	-	-	-	-	-	-
47	-	-	1.7	0.3	-	-	-	-	-	-	-	-	-	-	-
48	0.1	-	2.7	-	-	3.0	0.6	-	-	-	-	-	-	-	-
49	-	-	-	0.1	-	-	-	32.5	-	-	-	-	-	-	-
50	-	-	-	-	-	-	1.6	3.3	-	-	10.0	-	-	-	-
51	-	-	-	0.3	0.4	-	0.8	3.3	-	-	-	-	1.2	-	-
52	-	-	-	-	0.3	-	0.1	-	-	-	-	-	-	-	-
53	-	-	-	-	114.6	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
56	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-

* (-) indicates zero entry.

SECTION 2

THE DISTRIBUTION OF BIVALVE MOLLUSCS IN THE SOUTHEASTERN BERING SEA WITH EMPHASIS ON EIGHT SPECIES IN RELATION TO SEDIMENT

BEST DOCUMENT AVAILABLE

ACKNOWLEDGEMENTS

We would like to thank the following University of Alaska personnel: John Rose and Bill Kopplin for assistance onboard ship; Nora Foster for assistance in mollusc identifications; Dr. A. S. Naidu for discussions and assistance with sediment maps; Cydney Hansen, Bob Sutherland, Rosemary Hobson, Shirley Liss, for data procession and programing assistance, Ana Lea Vincent and Roseanne Lamoreaux for drafting assistance; the staff of the Publication Department for assistance with preparation of this section. Thanks go to the officers and the crew of the NOAA Ship *Miller Freeman* and the R/V *Discoverer* for their enthusiastic and competent assistance.

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OIL AND GAS DEVELOPMENT

The objectives of this study for the southeastern Bering Sea were to (1) make an inventory of all clam species, (2) make a qualitative and quantitative examination of the distribution of all clam species, (3) make sediment maps based on OCSEAP data and (4) relate the distribution of selected species of clams to depth and several sediment parameters.

Thirty-three species of bivalve molluscs were collected on the southeastern Bering Sea shelf. Eight species of common bivalves were chosen for detailed examination: the protobranchs *Nucula tenuis, Nuculana fossa, Yoldia amygdalea*, and the eulamellibranchs *Macoma calcarea, Tellina lutea, Spisula polynyma, Cyclocardia crebricostata*, and *Clinocardium ciliatum*.

The sediment phi values (ϕ) increased with distance from shore, depth, and decreased circulation. The lowest population densities of the eight species of bivalves occurred in shallow water in very coarse to fine sand ($<0-3.0\phi$) with very well to moderately well sorted ($<0.35-0.71\delta_I$) sediments; the biomass (g/m^2) for the eight species of clams was highest at this depth. The greatest population densities of the eight species of clams occurred in deep water in fine sand to medium silt ($>3.0-6.0\phi$) with moderately to very poorly sorted ($>0.71-4.0\delta_I$) sediments; the biomass (g/m^2) of the eight species of clams was lowest at this depth.

Nucula tenuis and *Macoma calcarea*, occurred over the greatest range of depth on the southeastern Bering Sea shelf while *Nuculana fossa, Yoldia amygdalea* and *Clinocardium ciliatum* distributions were confined to the mid-shelf area. *Cyclocardia crebricostata, Tellina lutea* and *Spisula polynyma* were confined primarily to the inshore shelf area. The depth distributions of the eight pelecypod species overlapped extensively. *Macoma calcarea* occurred at depths of 25-125 m with 97% of the clams collected between 50-100 m; *Cyclocardia crebricostata* at <25-75 m with 99% between 25-75; *Nucula tenuis* at <25-150 m with 92% between 50-100 m; *Nuculana fossa* at 50-175 m with 94% between 75-125 m; *Yoldia amygdalea* at 50->175 m with 92% between 75-100 m; *Tellina lutea* at <25-75 m with 78% between <25-50 m; *Spisula polynyma* at <25-100 m with 94% between 50-100 m; and *Clinocardium ciliatum* at 50-125 m with 97% between 50-75 m.

The sediment range for the bivalve species examined was as follows: *Macoma calcarea* in medium sand to coarse silt with 94% of the clams Collected in coarse silt; *Cyclocardia crebricostata* in coarse sand to coarse silt with 76% in fine to very fine sand; *Nucula tenuis* in fine sand to medium silt with 91% in very fine sand to coarse silt; *Nuculana fossa* in fine sand to medium silt with 84% in very fine sand to coarse silt; *Yoldia amygdalea* in fine sand to medium silt with 89% in very fine sand to coarse silt; *Tellina lutea* in very coarse sand to coarse silt with 70% in fine sand; *Spisula polynyma* in fine sand to coarse silt with 59% in fine sand to coarse silt; *Clinocardium ciliatum* in very fine sand to medium silt with 98% in very fine sand to coarse silt.

The sediment sorting for the eight bivalve species also overlapped extensively. *Macoma calcarea* occurred in moderately well to poorly sorted sediments with 98% of the clams collected within poorly sorted sediments; *Cyclocardia crebricostata* in well to poorly sorted with 58% within moderately sorted sediments; *Nucula tenuis* in very well to very poorly sorted with 75% within poorly sorted sediments; *Nuculana fossa* in moderately to very poorly sorted with 96% within poorly sorted sediments; *Yoldia amygdalea* in well to very poorly sorted with 89% within poorly sorted sediments; *Tellina lutea* in very well to very poorly sorted with 39% within well sorted and 44% in poorly sorted sediments; *Spisula polynyma* in very well to poorly sorted sediments with 32% within moderately well sorted and 59% at poorly sorted sediments; and *Clinocardium ciliatum* with 100% within poorly sorted sediments.

See general comments under Implications with Respect to Oil and Gas Development in Section 1.

II. INTRODUCTION

General Nature and Scope of Study

See general comments under this heading in Section 1.

It is the intent of this section to examine (1) the distribution and abundance of all clams collected in the southeastern Bering Sea by grab (Section 1, Appendix B; Haflinger, 1978) and pipe dredge, trawl (Feder *et al.*, 1978a, c; Feder and Jewett, in press), and clam dredge (Hughes, 1977), and (2) the relationship of clam distributions to depth and selected sediment parameters.

Relevance to Problems of Petroleum Development

See general comments under this heading in Section 1.

III. CURRENT STATE OF KNOWLEDGE

See general comments under this heading in Section 1.

The distribution of bivalves on the southeastern Bering Sea shelf was incompletely known prior to investigations by the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Past investigations of Bering Sea bivalves were centered primarily in the vicinity of the Gulf of Anadyr (see Feder, 1977 and Feder and Mueller, 1977 for literature review). Investigations of the infauna, including studies on bivalve molluscs from the southeastern and northeastern Bering Sea, are available (McLaughlin, 1963; Nieman, 1963; Stoker, 1978; Haflinger, 1978; Rowland, 1973; Sections 4 and 5). Rowland (1973) includes a discussion of the distribution of clams in relation to sediment parameters.

IV. STUDY AREA

The Bering Sea is an extension of the North Pacific, though separated by the Aleutian-Komondorsky Island systems and the Alaska Peninsula. The sill depths between the islands often exceed 4,000 m in depth (Filatova and Barsanova, 1964), permitting nearly unrestricted exchange with the north Pacific. In contrast, the exchange with the Arctic Ocean is limited to the Bering Strait with a sill depth less than 50 m. Thus, the fauna of the Bering Sea is predominantly of Pacific origin, with arctic forms limited to shallow-water organisms that can penetrate through the Bering Strait (Stoker, 1973, 1978).

The Bering Sea circulation south of St. Lawrence Island forms a counterclockwise gyre with Pacific water entering through the Aleutian passes and moving generally north along the eastern side of the Bering Sea, thus

BEST DOCUMENT AVAILABLE

endowing the eastern shelf with warmer bottom temperatures than the western side (Filatova and Barsanova, 1964; Stoker, 1978).

The submarine topography of the eastern Bering Sea shelf is uniformly level except for submarine canyons at the shelf break and a few shallow depressions. The average slope is approximately 1 m/3 km. The distribution of the sediments is controlled primarily by dominant currents and seasonal weather patterns.

The eastern Bering Sea shelf can be divided into five regions (Fig. 2.1; Sharma, 1972). Only three of the regions, each with its own sediment characteristics and distributions, are relevant to this report (Figs. 2.2-2.6): the southeastern shelf, including Bristol Bay; the central shelf, a broad region lying between St. Matthew and Nunivak Islands; and the outer shelf, a north-south oriented area running parallel to the continental margin (Nelson *et al.*, 1972). Each is discussed below.

The southeastern Bering shelf is bounded on the north and the east by the southern portions of the Kilbuck Mountains and on the south by the Alaska Peninsula. The drainage of numerous rivers and lakes, notably the Nushagak and Togiak Rivers from the north and the Kvichak River from the east, deposit sediments on the shelf. The bottom morphology consists of a series of banks in the north, and shallow depressions along the Alaska Peninsula. The nearshore sediments consist of well to poorly sorted gravel and coarse sand (-0.77-1.0ϕ) with moderately to poorly sorted, medium to fine sand (1.25-3.0ϕ) deposited on the mid-shelf of this region. Very poorly sorted silt and clay fractions (4.25-6.0ϕ) are deposited further offhsore (Figs. 2.2-2.6; Sharma, 1972, 1975; Sharma *et al.*, 1972).

The central Bering shelf extends from the Kuskokwim Delta north to the southern end of the Yukon Delta and the shores of St. Lawrence Island. Sediments from the Kuskokwim River, St. Matthew and Nunivak Islands, and the adjacent coast are deposited on the shelf. Nearshore sediments are well sorted to poorly sorted gravel and sand (-0.77-1.0ϕ), mid-shelf sediments are primarily poorly sorted sands (0.25-3.0ϕ), and offshore sediments are poorly to very well sorted silt and clay fractions (4.25-6.0ϕ) (Figs. 2.2-2.6; Hoskin, 1978; Sharma, 1972, 1975; Sharma *et al.*, 1972).

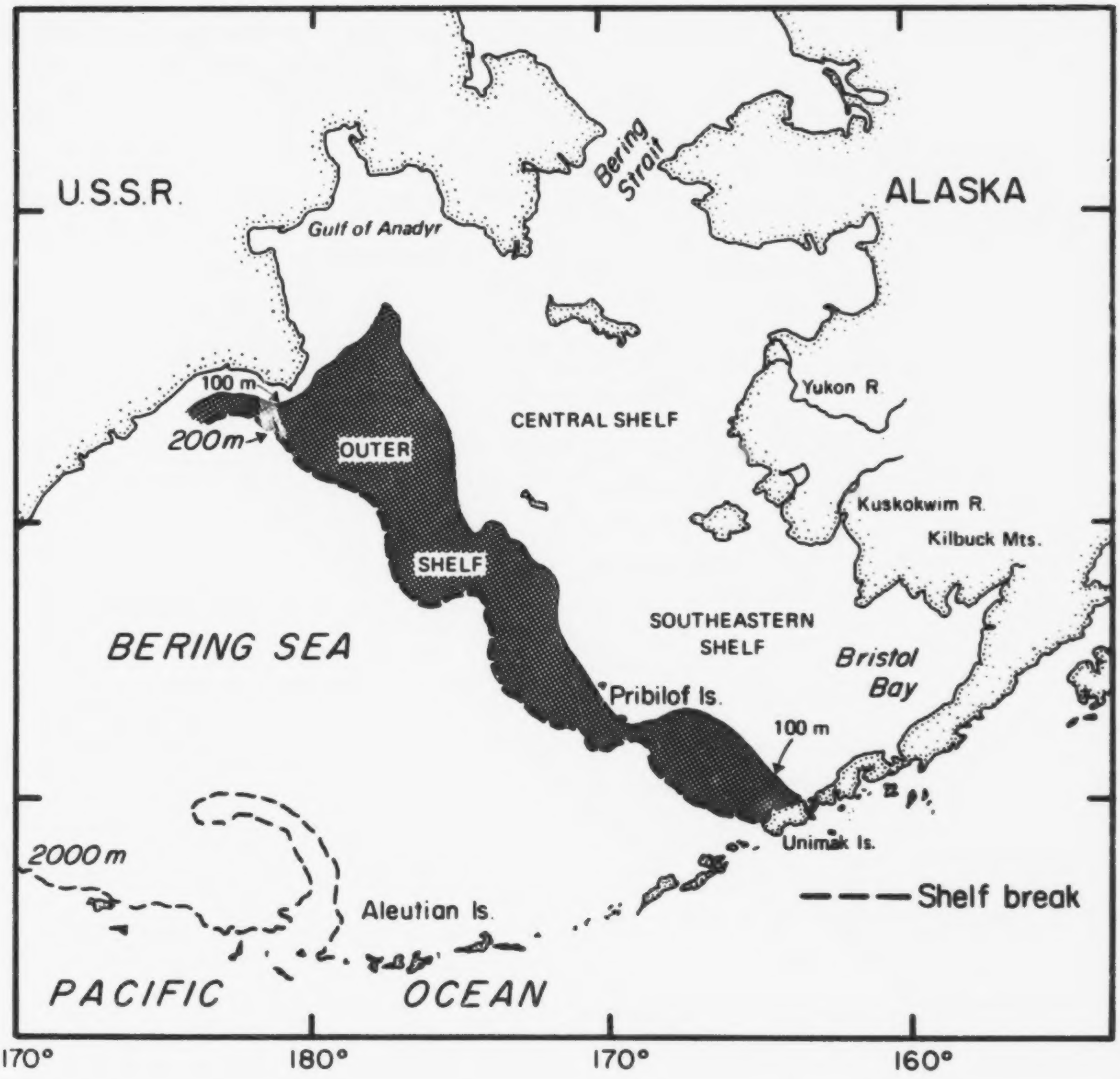

U.S.S.R.
ALASKA
Bering Strait
Gulf of Anadyr
100 m
200m
OUTER
SHELF
CENTRAL SHELF
Yukon R.
Kuskokwim R.
Kilbuck Mts.
SOUTHEASTERN SHELF
Bristol Bay
BERING SEA
Pribilof Is.
100 m
Unimak Is.
2000 m
Aleutian Is.
Shelf break
PACIFIC
OCEAN
170°
180°
170°
160°

Figure 2.1. Three regions of the eastern Bering Sea discussed in the present report (modified from Sharma, 1972).

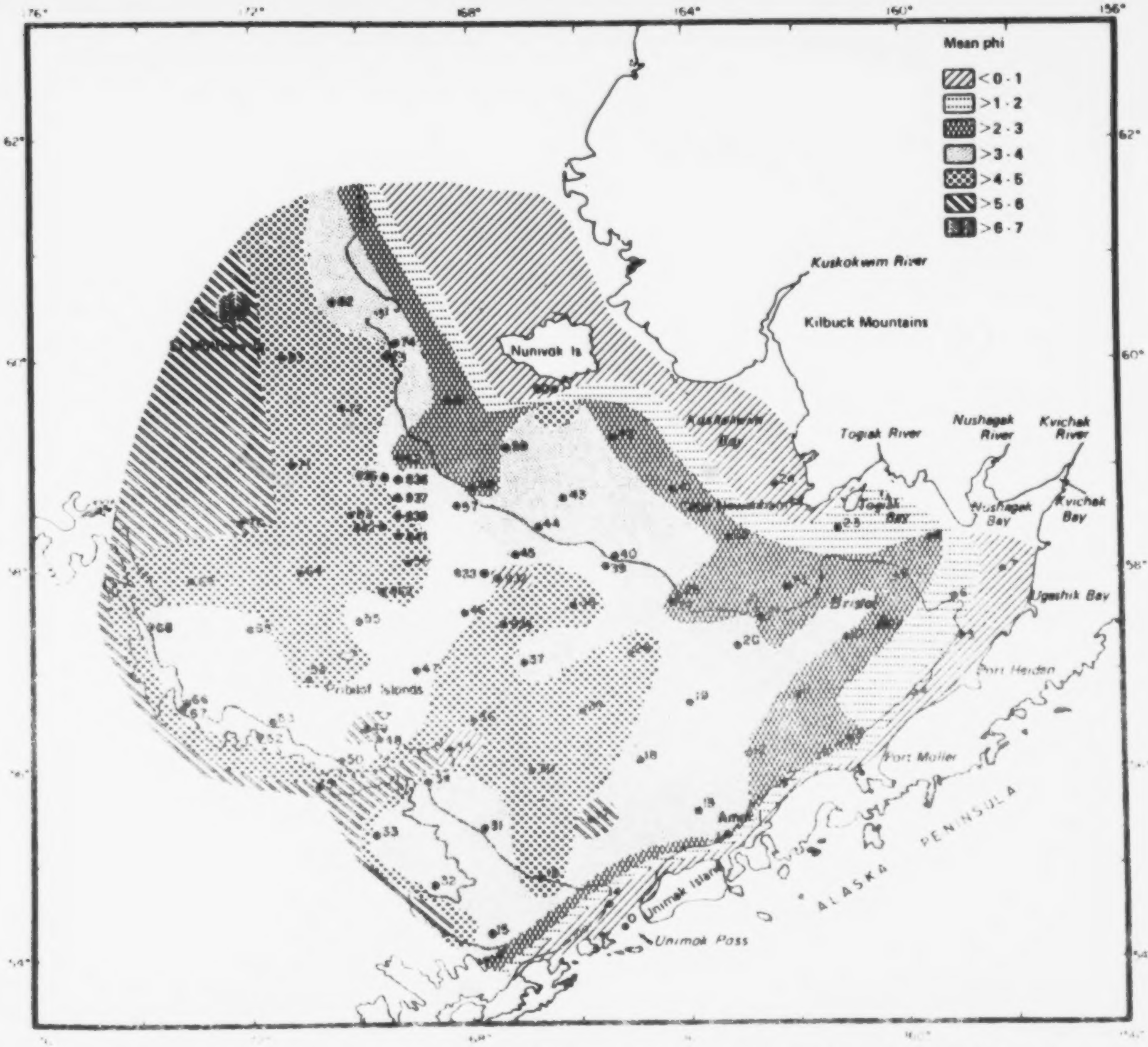

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Mean phi
▨ <0·1
▨ >1·2
▨ >2·3
▨ >3·4
▨ >4·5
▨ >5·6
▨ >6·7
Kuskokwim River
Kilbuck Mountains
Nunivak Is.
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol
Port Heiden
Port Moller
Pribilof Islands
Amak I.
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 2.2. Distribution of sediment size (mean phi) in the southeastern Bering Sea.

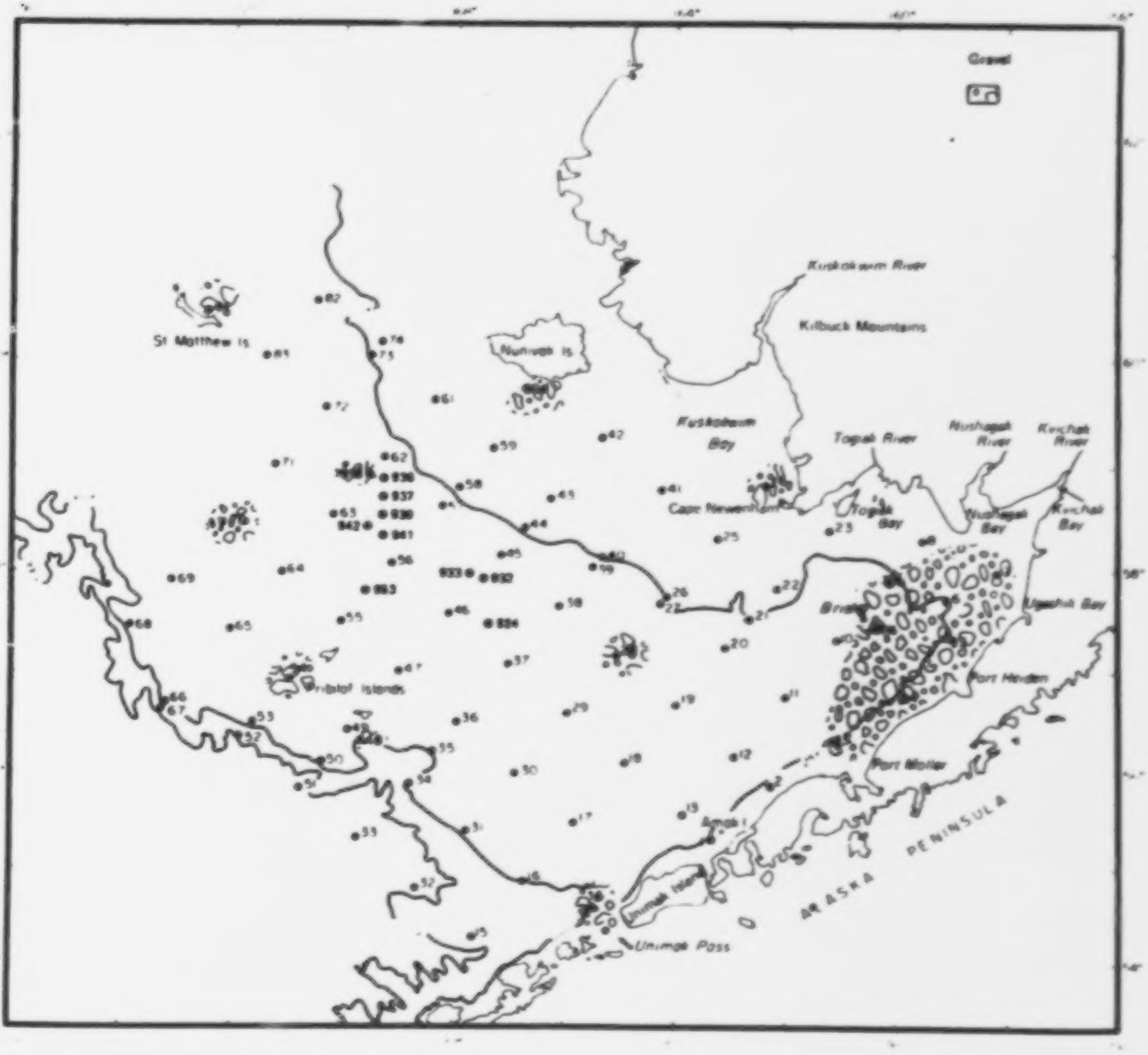

Gravel
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
82
76
75
81
72
61
62
71
59
42
58
41
63
44
23
25
69
64
45
22
26
27
68
65
55
46
38
21
20
37
66
67
53
52
36
29
19
50
35
30
18
12
51
34
33
31
13
32
16
15

Figure 2.3. Distribution of gravel in the southeastern Bering Sea.

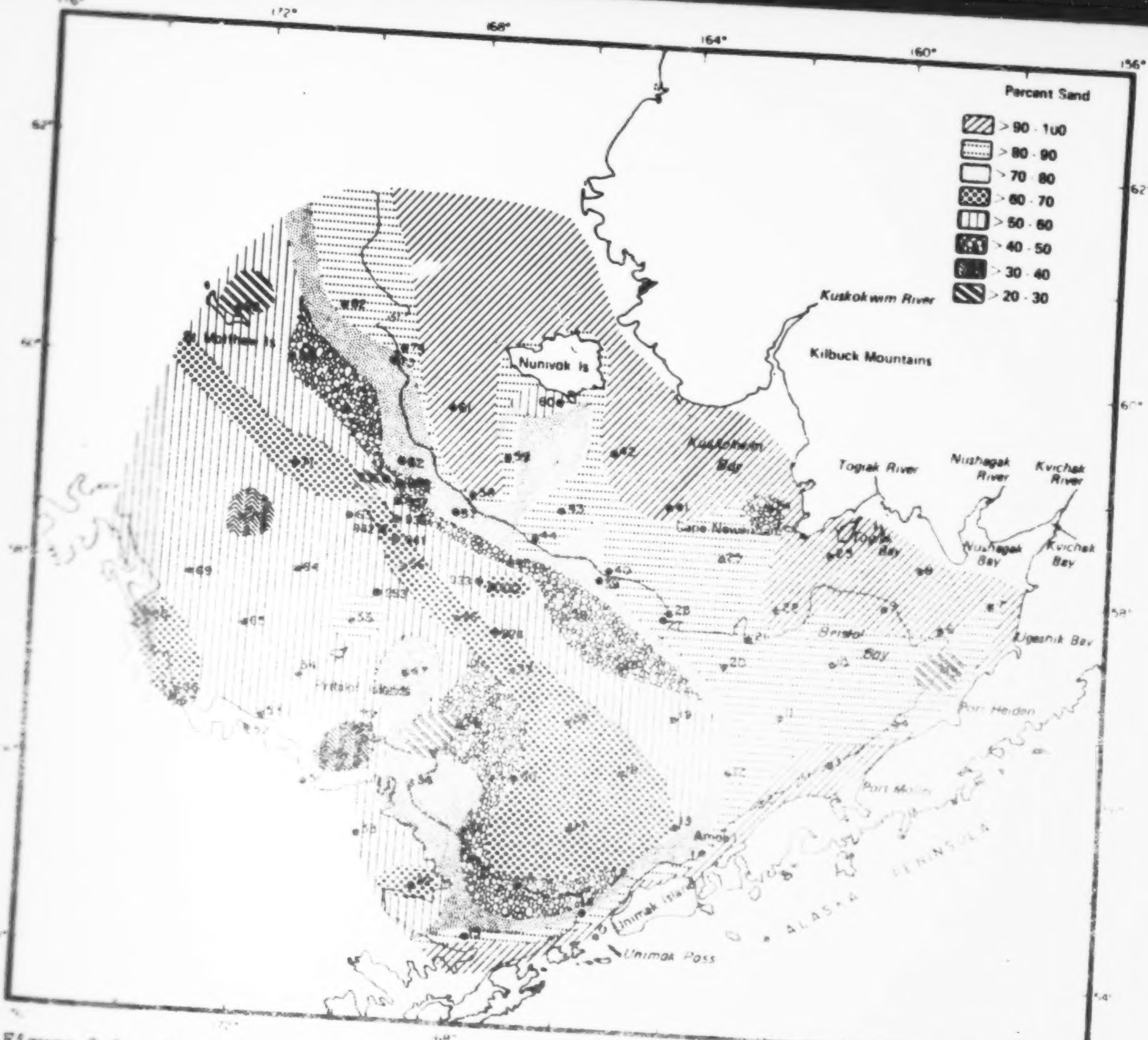

Percent Sand
> 90 - 100
> 80 - 90
> 70 - 80
> 60 - 70
> 50 - 60
> 40 - 50
> 30 - 40
> 20 - 30
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Cape Newenham
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 2.4. Distribution of sand fraction in the southeastern Bering Sea.

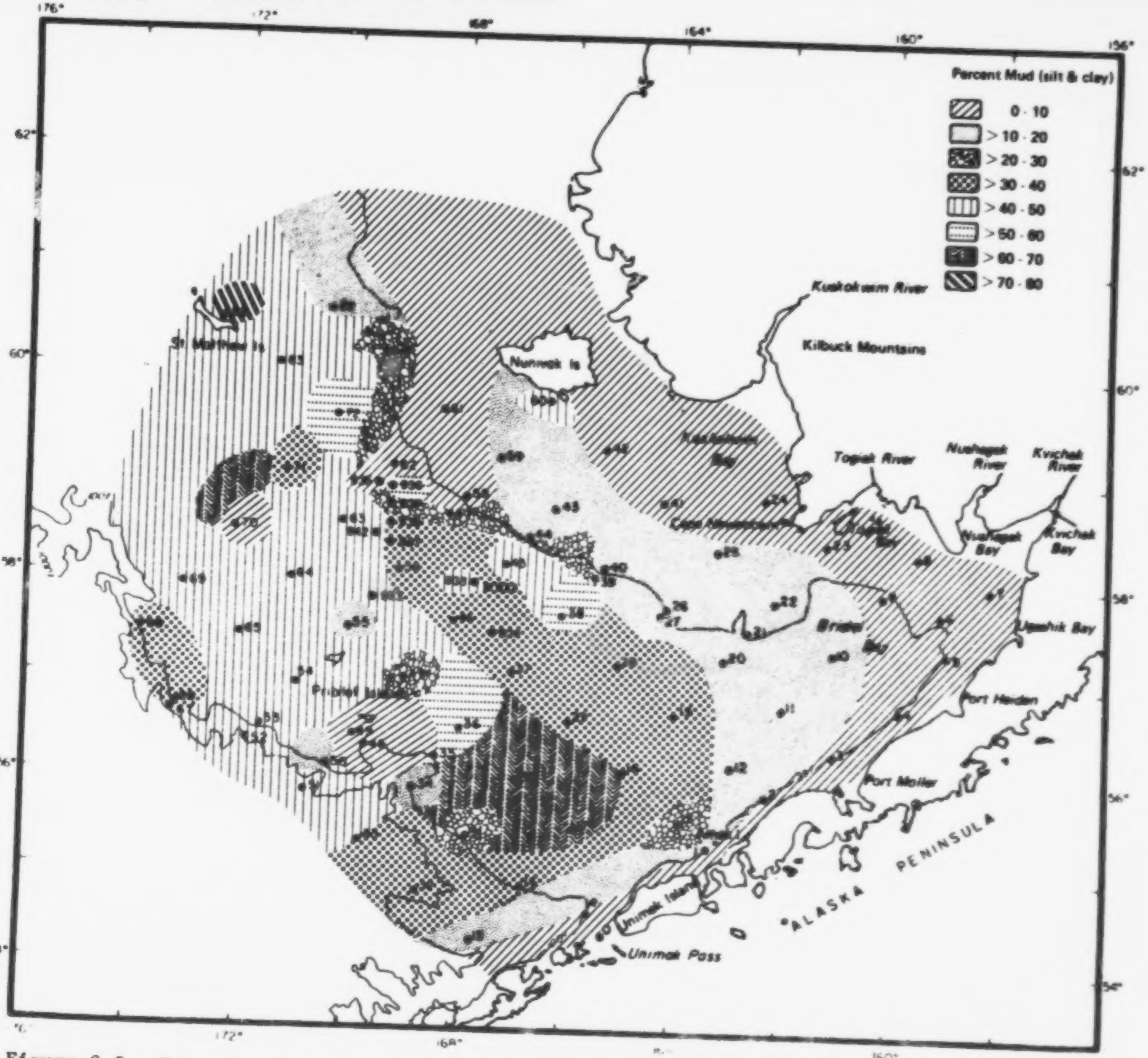

Percent Mud (silt & clay)
0 - 10
> 10 - 20
> 20 - 30
> 30 - 40
> 40 - 50
> 50 - 60
> 60 - 70
> 70 - 80
Kuskokwim River
Kilbuck Mountains
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Togiak Bay
Nushagak River
Kvichak River
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
ALASKA PENINSULA
Unimak Island
Unimak Pass
St Matthew Is
Pribilof Islands
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 2.5. Distribution of mud fraction in the southeastern Bering Sea.

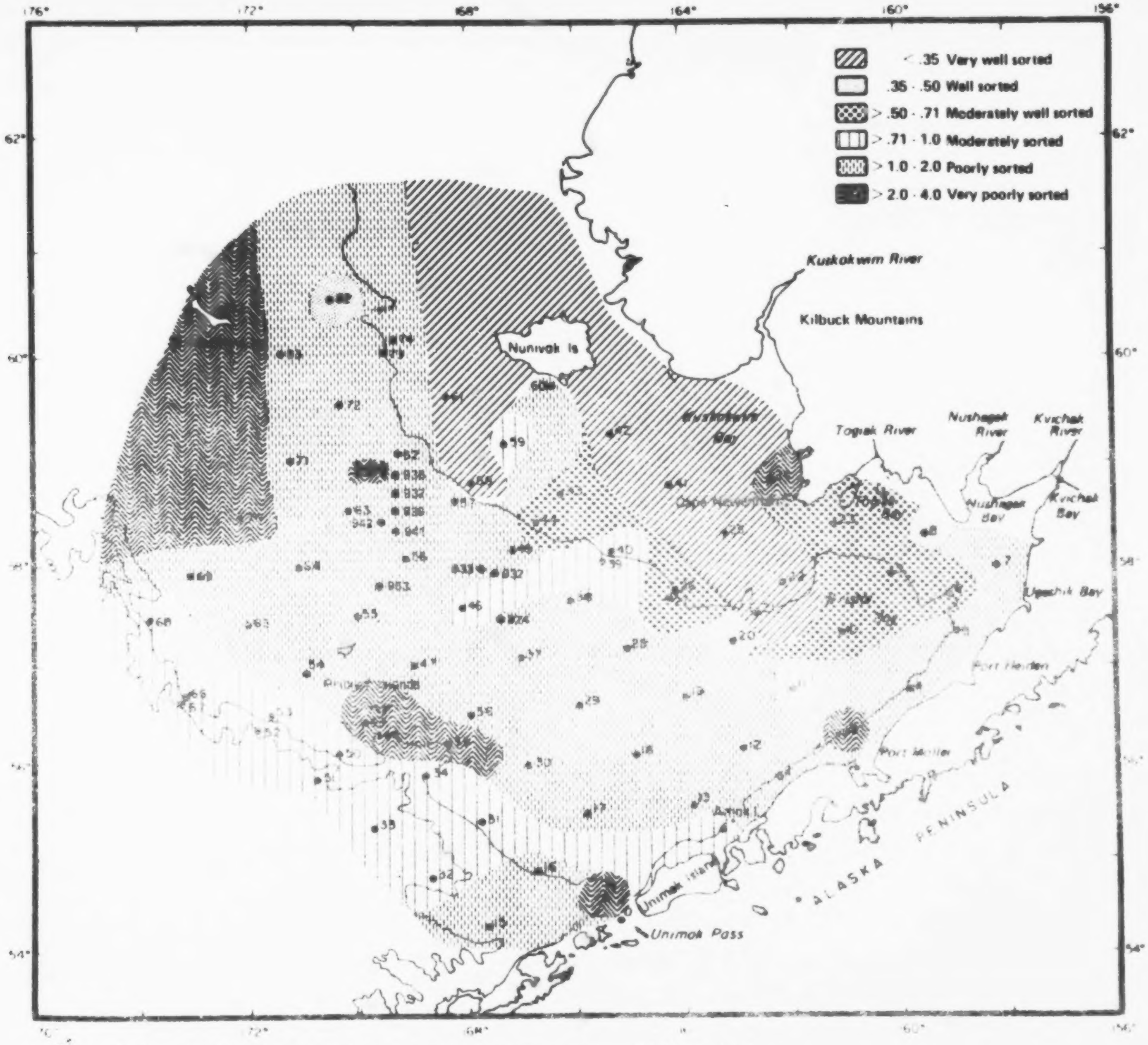

< .35 Very well sorted
.35 - .50 Well sorted
> .50 - .71 Moderately well sorted
> .71 - 1.0 Moderately sorted
> 1.0 - 2.0 Poorly sorted
> 2.0 - 4.0 Very poorly sorted
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Nushagak River
Kvichak River
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Amak I.
Unimak Island
Unimak Pass
Pribilof Islands
ALASKA PENINSULA

Figure 2.6. Sediment sorting in the southeastern Bering Sea.

The outer Bering shelf, parallels the continental margin. The bottom contour is steepest near the Pribilof Islands and slopes gradually to the north. At the southern extent of the outer Bering shelf, north of Unimak Island, the shelf is about 120 km wide; extending north it becomes narrow near the Pribilof Islands, but widens again to a maximum width of 350 km near the Gulf of Anadyr. Sediments are generally moderately to very poorly sorted (Fig. 2.6). Sands are predominant at lesser depths (1.0-4.0ϕ), while silt and clay fractions (4.25-6.0ϕ) are deposited in mid region and further offshore (Figs. 2.2-2.6; Sharma, 1972, 1975; Sharma *et al.*, 1972). Multiple sediment sources and intermixing increase the complex sediment distribution in the outer Bering shelf. Sediments from the southern portions of the outer shelf are dominated by detrital materials originating in the Bristol Bay and Kuskokwim River drainages (Sharma, 1972). The central portion of the outer Bering shelf is covered by sediments from the adjacent coast, offshore islands, and the Kuskokwim River. The organic matter in the outer Bering shelf sediments is higher than in sediments from the southeastern and central shelves (Sharma, 1972, 1975; Sharma *et al.*, 1972).

The three shelf regions, in general, show sediment particle size decreasing with increasing depth and distance from shore (Fig. 2.1). Suspended load in the water column varies seasonally. During the period of ice cover, the suspended load of surface water is low but increases during spring phytoplankton blooms. Following storms, there is an increase in suspended load attributed to resuspension of bottom material by wave action (see Sharma, 1972; Rees *et al.*, 1977; Sanders, 1958, 1960, for discussions). Twenty mg/ℓ of sediment in the near-bottom waters have been reported for the Bering Sea (Lisitsyn, 1966).

A series of van Veen grab stations were occupied on a grid established in the southeastern Bering Sea (Fig. 2.7; Section 1). Forty-four of these stations were sampled with a pipe dredge. An extensive grid on the shelf was occupied by trawl (see Feder *et al.*, 1978c; Feder and Jewett, in press for location of trawl grid). A limited number of stations was examined inshore with a clam dredge (Section 4).

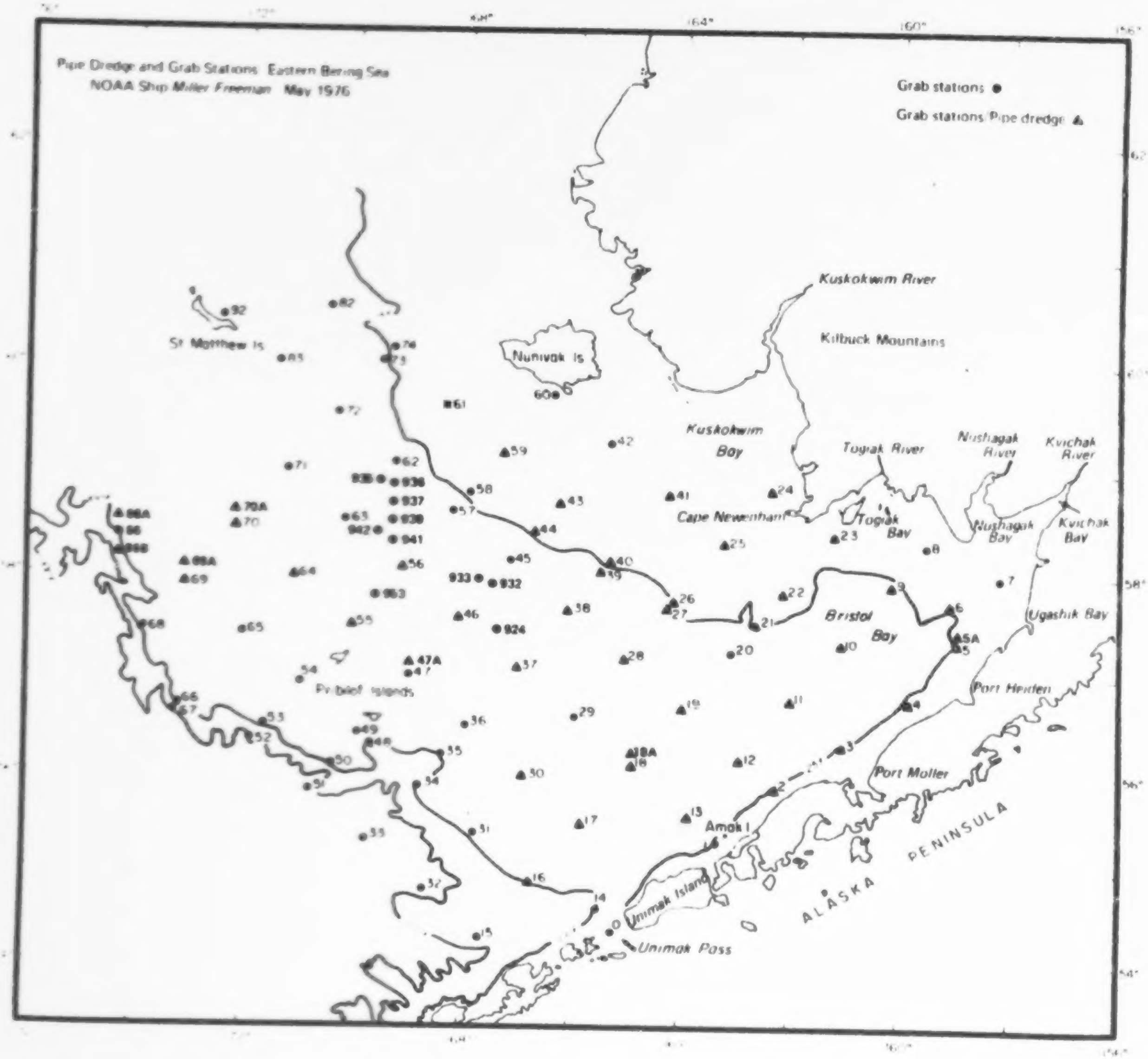

Pipe Dredge and Grab Stations Eastern Bering Sea
NOAA Ship Miller Freeman May 1976
Grab stations ●
Grab stations/Pipe dredge ▲
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
164°
160°
58°

Figure 2.7. Infaunal stations occupied in the eastern Bering Sea, May 1976.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Samples were collected by van Veen grab from the NOAA Ships *Discoverer* and *Miller Freeman* in 1975 (Appendix 1.B), otter trawl from the NOAA Ship *Miller Freeman* in 1975 and 1976 (Feder *et al.*, 1978c), clam dredge from M/V *Smaragd* in 1977 (see Appendix 4.A for stations), and pipe dredge (0.7 x 0.5 m) in 1976 from the NOAA Ship *Miller Freeman*. A stainless steel screen with a mesh of 1 mm^2 was inserted at the base of the pipe dredge on sandy bottom; 2 mm^2 mesh screen was routinely used for all fine sediments. The grab and pipe dredge contents were washed over a 1 mm^2 screen, and all invertebrates left on the screen preserved in buffered 10% formalin.

Sediment samples were collected with a van Veen grab by the NOAA Ship *Discoverer* in September-October 1975, and were analyzed by Hoskin (1978). Values to the second decimal place for sediment size (ϕ values*) included in the text are directly from Hoskin (1978) also, see Table 2.I for the data from Hoskin (1978). All of the general values (based on Hoskin, 1978) of mean sediment size, distribution of gravel, percent sand, percent mud, and sorting characteristics were tabulated and are included.

Eight of the most common species of bivalve molluscs collected--*Nucula tenuis, Nuculana fossa, Cyclocardia crebricostata, Clinocardium ciliatum, Macoma calcarea, Yoldia amygdalea, Spisula polynyma*, and *Tellina lutea*--were selected for detailed study. *Tellina lutea* and *Spisula polynyma*, while not frequently taken or collected quantitatively with the gear used in this study, were included here because of their potential commercial value (the latter two species were commonly taken by hydraulic clam dredge; Section 4, 5; Appendix 2.A-C). All calculations, in the analyses included below, are based on 1975 grab data (Section 1). Distribution maps and

---

*The grade scale often used in the past for sediments is the Wentworth scale which is a logarithmic scale of sizes in millimeters. The ϕ scale, devised by Krumbein (see Pettijohn, 1957) is a much more convenient way of presenting data than if the values are expressed in millimeters, and is used almost entirely in recent work. Phi (ϕ) is the negative logarithm (to the base 2) of the diameter of particles. To avoid negative numbers for the various sand grades and finer material the log was multiplied by -1, or phi = ${}_2$-log$_2$ diameter (mm). ϕ values represent the inverse of any mean sediment size, e.g. gravel = >-1ϕ (Folk, 1974; Folk and Ward, 1957; Pettijohn, 1957; Tables 2.I and 2.II).

TABLE 2.I

SEDIMENT DATA FROM R/V *DISCOVERER* VAN VEEN GRAB DATA - 1975
(Hoskin, 1978)

Station No.	Mean ϕ*	Median ϕ	Wentworth Size Classes	Size Base on % gravel, sand, silt, clay	% Gravel	% Sand	% silt	% Clay
1	3.33	3.20	very fine sand	--	0	72.6	19.57	7.82
3	2.31	2.44	fine sand	sand	2.04	97.96	0	0
5	-.77	-1.52	very coarse sand	sandy gravel	77.03	22.97	0	0
6	1.51	1.57	medium sand	sand	0	100	0	0
7	.44	1.34	coarse sand	gravely sand	18.49	81.51	0	0
8	2.43	2.58	fine sand	sand	0	100	0	0
9	2.05	2.16	medium sand	gravely sand	6.29	93.71	0	0
10	2.52	2.44	fine sand	clay-silt sand	0	88.47	5.32	6.22
11	2.84	2.62	fine sand	clayey sand	0	84.67	5.66	9.67
13	3.64	3.49	very fine sand	silty sand	0	61.04	30.73	8.23
14	.66	.93	coarse sand	gravely sand	14.26	46.97	6.46	5.30
16	4.17	3.59	very fine sand	silty sand	0	62.34	28.01	9.65
17	5.17	4.65	very fine sand	sandy silt	0	36.44	49.02	13.64
19	3.92	3.62	very fine sand	silty sand	0	59.27	33.28	7.45
20	3.02	2.87	very fine sand	sand	0	85.79	6.41	7.80
21	2.66	2.59	fine sand	sand	0	89.43	3.75	6.82
22	2.46	2.50	fine sand	sand	0	90.70	2.80	6.50
23	1.80	1.83	medium sand	sand	0	98.08	.23	1.69
24	-.65	-1.02	very coarse sand	sandy gravel	51.01	45.08	.17	3.74
25	2.44	2.49	fine sand	clayey sand	0	89.98	.31	9.70
26	2.99	2.85	very fine sand	sand	0	85.77	7.02	7.21
27	3.08	2.90	very fine sand	sand	0	84.77	8.25	6.98
28	4.26	3.66	very fine silt	silty sand	8.74	45.94	35.85	6.47
29	4.04	3.51	very fine sand	silty sand	0	62.05	30.99	6.96
31	3.58	3.34	very fine sand	sand	0	76.90	15.27	7.83
32	3.59	3.55	very fine sand	silty sand	0	68.60	25.87	5.53
33	3.75	3.60	very fine sand	silty sand	0	59.37	34.33	6.31
34	3.52	3.31	very fine sand	silty sand	0	74.58	17.45	7.97
35	-.55	-1.68	very coarse sand	sand	0	24.58	4.17	4.99

TABLE 2.I

CONTINUED

Station No.	Mean ϕ	Median ϕ	Wentworth Size Classes	Size Base on % gravel, sand, silt, clay	% Gravel	% Sand	% silt	% Clay
36	4.39	4.29	coarse silt	sandy silt	66.26	45.16	47.12	7.72
37	3.70	3.53	very fine sand	silty sand	0	65.63	25.70	8.66
38	4.24	4.08	very fine silt	silty sand	0	47.07	44.28	8.65
39	3.62	3.17	very fine sand	sand	0	76.73	15.37	7.90
40	3.21	2.91	very fine sand	sand	0	84.04	7.65	8.30
41	2.59	2.64	fine sand	sand	0	96.91	.63	2.46
42	2.76	2.74	fine sand	sand	0	97.51	1.26	1.22
43	3.12	2.88	very fine sand	sand	0	85.0	7.74	7.26
44	3.09	2.85	very fine sand	sand	0	85.1	8.67	6.23
45	3.94	3.61	very fine sand	silty sand	0	59.4	34.29	6.31
46	3.63	3.58	very fine sand	silty sand	0	60.63	31.22	8.15
47	3.43	2.97	very fine sand	silty sand	0	71.51	21.35	7.15
48	.74	2.46	coarse sand	sandy silt	24.87	60.52	6.80	7.81
49	5.59	4.58	very fine silt	sandy silt	0	31.14	53.66	15.2
50	5.23	2.91	very fine sand	sand	0	31.86	10.38	7.76
54	4.40	3.65	very fine sand	sand	2.64	57.12	30.48	9.76
55	3.57	2.77	very fine sand	sand	0	81.7	11.16	7.14
56	3.26	3.65	very fine silt	silty sand	0	62.41	30.87	6.72
57	3.68	2.90	very fine sand	sand	0	77.02	16.41	6.56
58	2.76	2.84	fine sand	sand	0	98.69	.73	.58
59	3.36	2.96	very fine sand	sand	0	83.18	9.18	7.64
60	4.35	3.55	very fine silt	silty sand	20.26	55.27	37.44	7.29
61	2.81	2.78	fine sand	sand	0	99.73	.27	0
62	2.99	3.04	fine sand	silty sand	0	71.69	20.74	7.58
63	4.71	3.96	very fine silt	silty sand	0	50.49	39.50	10.01
64	4.83	3.58	very fine silt	silty sand	0	56.49	31.05	12.46
65	4.29	3.64	very fine silt	silty sand	0	59.59	32.13	8.28
66	3.57	3.37	fine sand	silty sand	0	68.72	24.18	7.10
68	3.98	3.58	very fine sand	silty sand	0	63.37	29.59	7.05
69	4.24	3.53	very fine silt	silty sand	0	58.06	33.85	8.09

TABLE 2.I

CONTINUED

Station No.	Mean ϕ	Median ϕ	Wentworth Size Classes	Size Base on % gravel, sand, silt, clay	% Gravel	% Sand	% silt	% Clay
70	5.71	4.60	very fine silt	silty sand	.73	39.23	43.22	16.82
71	4.10	3.50	very fine silt	silty sand	0	69.01	22.95	8.04
72	4.59	4.20	very fine silt	silty sand	0	46.05	45.06	8.89
73	4.37	3.30	very fine silt	silty sand	0	70.62	19.84	9.54
82	4.50	2.93	very fine silt	sand	0	88.17	5.20	6.63
83	4.53	3.96	very fine silt	silty sand	0	50.82	39.43	9.75
92	7.06	5.45	very fine silt	clumey sandy silt	.24	26.13	48.55	25.04
924	4.5	--	coarse silt	--	--	--	--	--
932	.5	--	coarse sand	--	--	--	--	--
933	3.5	--	very fine sand	--	0	68.60	25.87	5.53
935	3.5	--	very fine sand	--	0	59.37	34.33	6.31
936	3.5	--	very fine sand	--	66.26	24.58	4.17	4.99
937	5.5	--	very fine sand	--	0	45.16	47.12	7.72
939	4.5	--	coarse silt	--	--	--	--	--
941	4.5	--	coarse silt	--	--	--	--	--
942	4.5	--	coarse silt	--	--	--	--	--
953	4.5	--	coarse silt	--	--	--	--	--

---

*ϕ = $\log_2$ size in mm.

TABLE 2.II

A COMPARISON OF FIVE METHODS USED FOR DESCRIPTION OF SEDIMENTS (Folk, 1974)

	U. S. Standard Sieve Mesh No.		Millimeters (1 Kilometer)	Microns	Phi (ϕ)	Wentworth Size Class
GRAVEL					-20	
			4096		-12	
			1024		-10	
	Use		256		- 8	Boulder (-8 to -12ϕ)
	wire		64		- 6	Cobble (-6 to -8ϕ)
	squares		16		- 4	Pebble (-2 to -6ϕ)
	5		4		- 2	Pebble (-2 to -6ϕ)
	6		3.36		-1.75	Granule
	7		2.83		-1.5	Granule
	8		2.38		-1.25	Granule
	10		2.00		-1.0	Granule
SAND	12		1.68		-0.75	Very coarse sand
	14		1.41		-0.5	Very coarse sand
	16		1.19		-0.25	Very coarse sand
	18		1.00		0.0	Very coarse sand
	20		0.84		0.25	Coarse sand
	25		0.71		0.5	Coarse sand
	30		0.59		0.75	Coarse sand
	35	1/2	0.50	500	1.0	Coarse sand
	40		0.42	420	1.25	Medium sand
	45		0.35	350	1.5	Medium sand
	50		0.30	300	1.75	Medium sand
	60	1/4	0.25	250	2.0	Medium sand
	70		0.210	210	2.25	Fine sand
	80		0.177	177	2.5	Fine sand
	100		0.149	149	2.75	Fine sand
	120	1/8	0.125	125	3.0	Fine sand
	140		0.105	105	3.25	Very fine sand
	170		0.088	88	3.5	Very fine sand
	200		0.074	74	3.75	Very fine sand
	250	1/16	0.0625	62.5	4.0	Very fine sand
MUD	270		0.053	53	4.25	Coarse silt
	325		0.044	44	4.5	Coarse silt
			0.037	37	4.75	Coarse silt
		1/32	0.031	31	5.0	Medium silt
	Analyzed	1/64	0.0156	15.6	6.0	Medium silt
		1/128	0.0078	7.8	7.0	Fine silt
	by	1/256	0.0039	3.9	8.0	Very fine silt
			0.0020	2.0	9.0	Clay (some use 2μ or 9ϕ as the clay boundary)
	Pipette		0.00098	0.98	10.0	
			0.00049	0.49	11.0	
	or		0.00024	0.24	12.0	
			0.00012	0.12	13.0	
	Hydrometer		0.00006	0.06	14.0	

the percent composition by depth for the eight species of clams are included in this report. A compilation of density and biomass data for all other species of pelecypods collected by van Veen grab and pipe dredge in the study is also presented. Density and biomass data for all species have been submitted to OCSEAP on magnetic tape for submission to the National Oceanographic Data Center.

The percent of the total number and biomass of each of the eight species of clams (*N. tenuis*, *N. fossa*, *C. crebricostata*, *C. ciliatum*, *M. calcarea*, *S. polynyma*, *Y. amygdalea*, *T. lutea*) collected by grab is calculated relative to (1) sediment size - phi (ϕ), (2) sorting, and (3) depth range. All calculations are based on 1975 van Veen grab data.

Three types of maps are included for each species of clam (except for *Spisula polynyma*): (1) a total distribution for each species of clam taken by all gear (grab, pipe dredge, clam dredge, trawl) used on cruises by Feder and associates (Feder *et al.*, 1978a, b, c), and (2) a distribution of clams taken by pipe dredge only, together with associated sediment size (ϕ) values derived from sediment samples collected by the same dredge, and (3) a quantitative distribution of each species of clam taken by grab in 1975.

All calculations were accomplished with the Honeywell 66/40 computer.

VI. RESULTS

Thirty-three species of bivalve molluscs were collected on the southeastern Bering Sea shelf (Appendix 2.A).

Nucula tenuis was broadly distributed (Fig. 2.8) over the southeastern Bering Sea shelf with greatest abundance at Stations 1, 11, 12, 18, 19, 28, 29, 30, 63, 71, 72, 82, 83, 935, 937, 939 and 942 (Figs. 2.8, 2.9, 2.10; Appendices 2.A, 2.B). It was present at 77% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 19, 28, 29, 63, 71, 83, and 935 (Appendix 2.C). *Nucula tenuis* was associated with sediment types ranging from fine sand to medium silt (2.25-5.7ϕ; Tables 2.I, 2.II; Figs. 2.2-2.10; Table 2.III). Major Component of Collection: Ninety-one percent (91%) of *N. tenuis* collected occurred in fine sand to medium silt (3.0-5.0ϕ) with 75% of the clams at sediment sorting values from 1.0-2.0

Text continued on page 158.

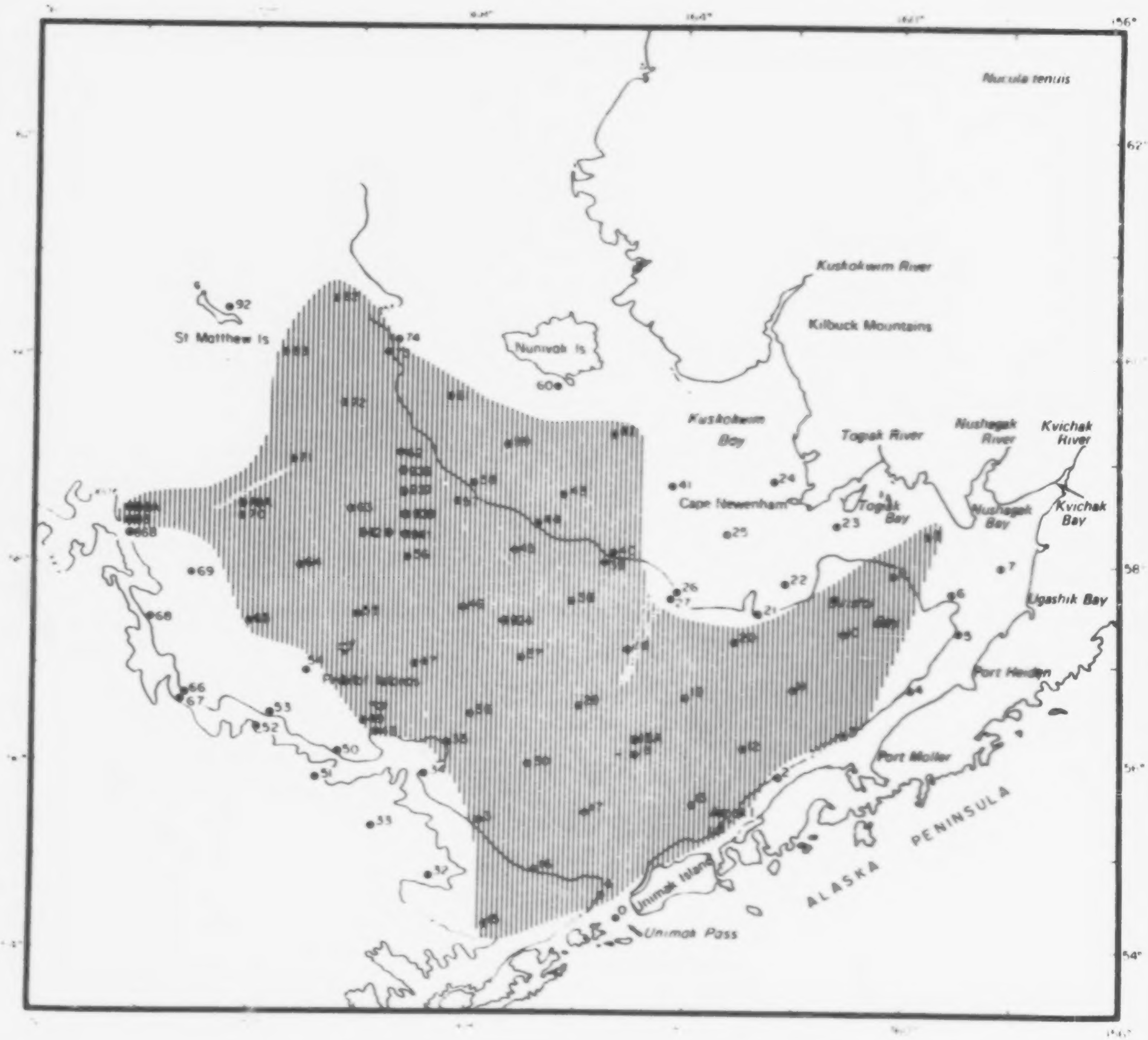

Nucula tenuis
62°
58°
54°
56°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
92
Nunivak Is
60
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
41
24
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
25
23
7
22
26
27
21
6
Ugashik Bay
Bristol Bay
5
Port Heiden
69
68
Pribilof Islands
66
67
53
52
50
51
33
32
Port Moller
ALASKA PENINSULA
Unimak Island
Unimak Pass

Figure 2.8. Distribution of *Nucula tenuis* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

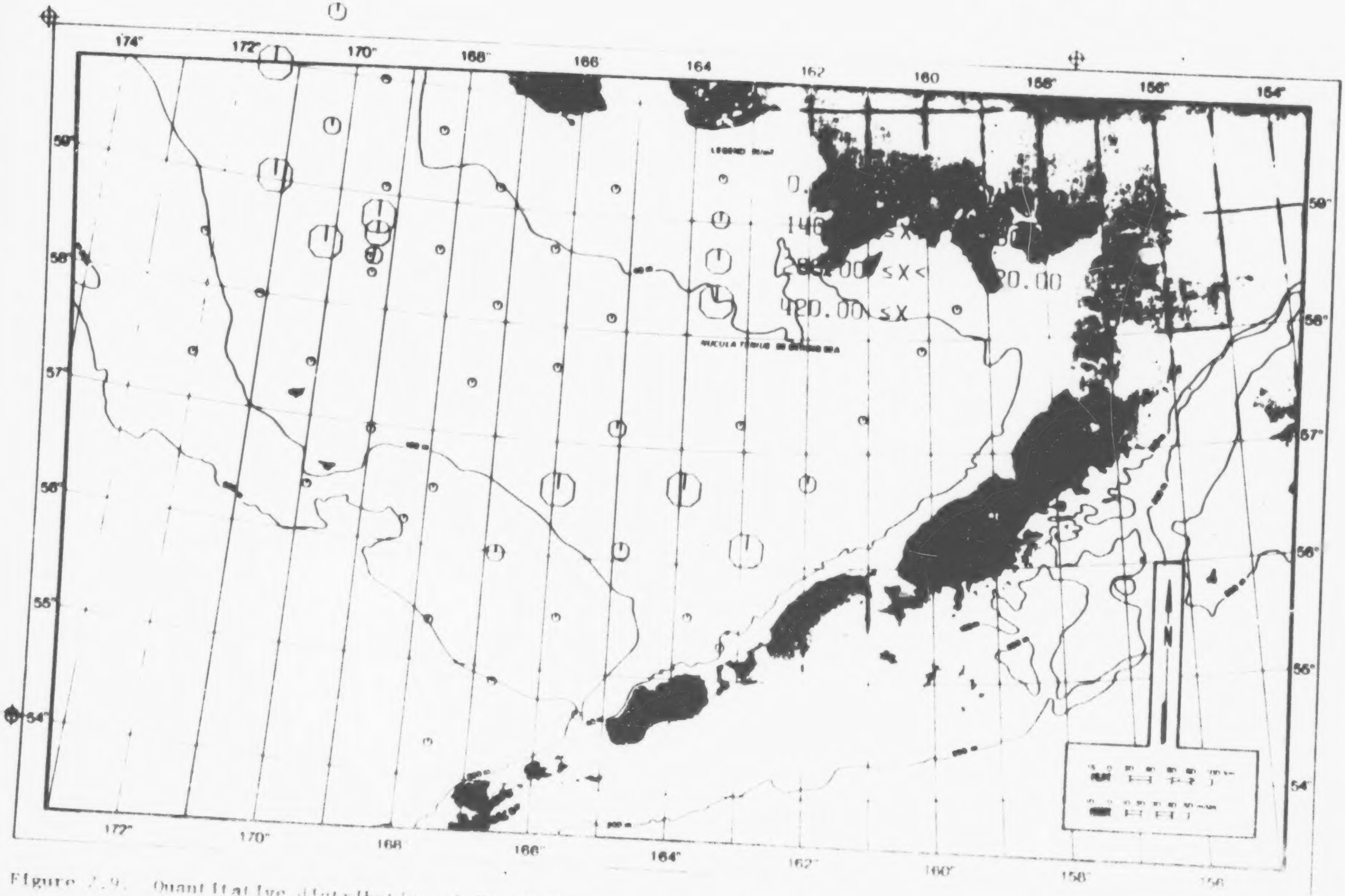
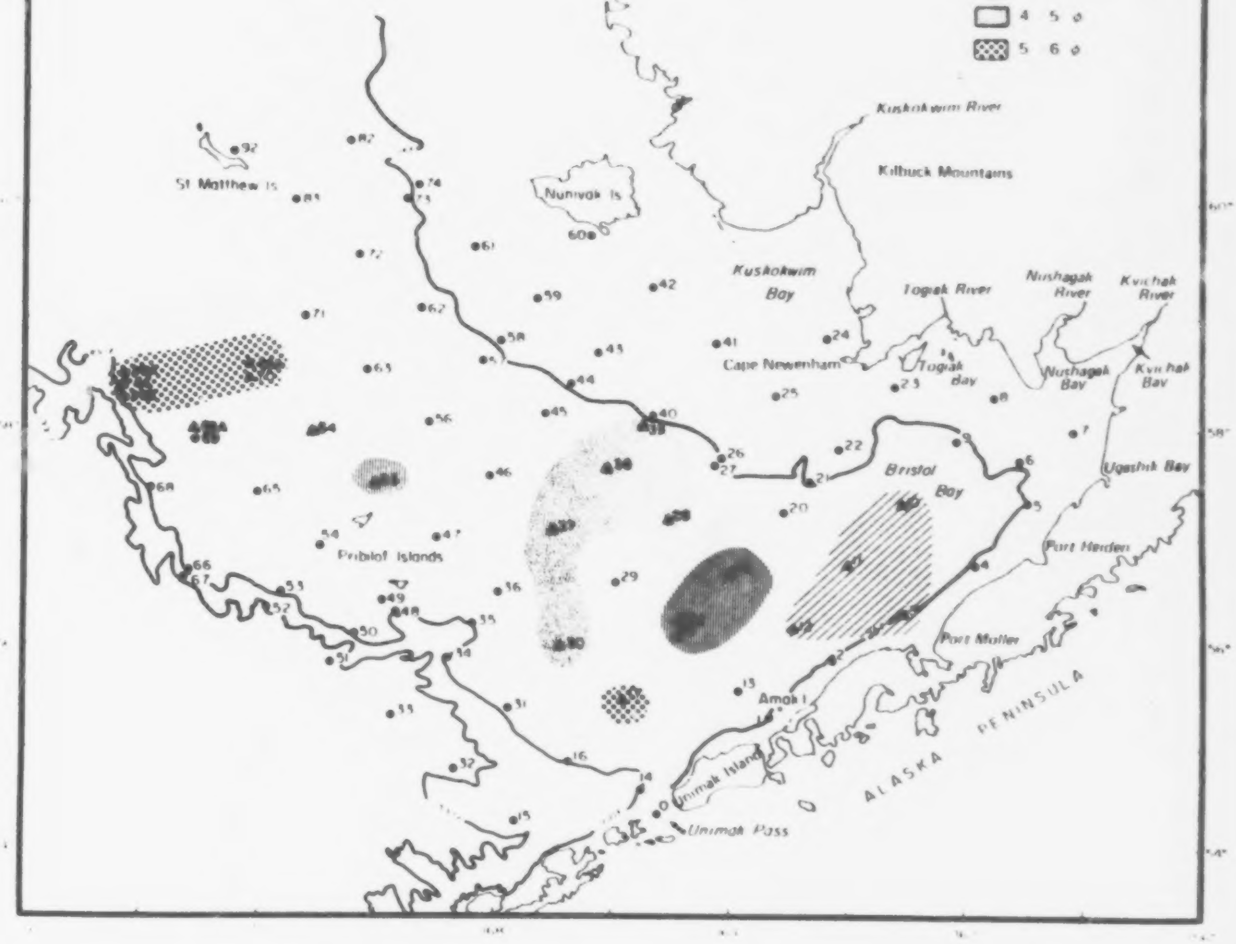

174°
172°
170°
168°
166°
164
162
160
158°
156°
154°
59°
58°
57°
56°
55°
54°
0.
146
≤X
280.00 ≤X<
20.00
420.00 ≤X
NUCULA TENUIS
N

Figure 2.9. Quantitative distribution of *Nucula tenuis* taken by [illegible]



Nucula tenuis
2 3 φ
3 4 φ
4 5 φ
5 6 φ
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 2.10. Distribution of *Nucula tenuis* collected by pipe dredge and associated phi values.

TABLE 2.III

PERCENTAGE OF PELECYPODS COLLECTED AT EACH Phi VALUE BASED ON GRAB SAMPLES

(Based on counts/meter squared)

	Phi. Values						
Species	-.8-<0	0-<1	1-<2	2-<3	3-<4	4-<5	5-<6
Nucula tenuis				3	40	51	6
Nuculana fossa					12	84	4
Cyclocardia crebricostata			5	18	76	1	
Tellina lutea	2		7	70	3	18	
Macoma calcarea				2	4	94	
Clinocardium ciliatum					1	98	1
Yoldia amygdalea				1	3	89	7
Spisula polynyma				41	14	45	

(Table 2.IV). Ninety-two percent (92%) of *N. tenuis* collected occurred at 50-100 m (Table 2.V; Appendix 2.D). Minor Component of Collection: Nine percent (9%) of the clams collected occurred in either fine sand (2.3-2.8ϕ) or medium silt (5.7ϕ); 3% of the individuals were at sediment sorting values of <.35, 4% at .35-.50, 8% at .71-1.0, and 10% at 2.0-4.0. One percent (1%) of *N. tenuis* occurred at depths of <25 m (coarse sand), 1% at 25-50 m (fine sand) and 6% at 100-150 m (medium silt).

Nuculana fossa was well distributed over the outer portion of the central and southeastern shelf and extending onto the outer shelf (Figs. 2.1, 2.2, 2.12). The greatest abundance of this species occurred at Stations 18, 28, 29, 36, 47, 49, 64, 65, 70,71 and 72 (Figs. 2.11, 2.13; Appendices 2.A, 2.B). The clam was present at 36% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 29, 47, 64 and 71. *Nuculana fossa* was associated with sediment types ranging from fine sand to medium silt (3.0-5.7ϕ; Tables 2.I, 2.II; Figs. 2.2-2.6, 2.11, 2.12, 2.13; Table 2.III). Major Component of Collection: Eighty-four percent (84%) of *N. fossa* occurred in very fine sand to medium silt (4.0-5.0ϕ) with 96% of the clams at sediment sorting values from >1.0-2.0 (Table 2.IV). Ninety-four percent (94%) of *N. fossa* occurred at 75-100 m (Table 2.V; Appendix 2.D). Minor Component of Collection: Twelve percent (12%) of the clams occurred in fine to very fine sand (3.0-4.0) and 4% in medium silt (5.7ϕ) with 1% of the species at sediment sorting values of >.71-1.0 and 3% at >2.0-4.0. Four percent (4%) of *N. fossa* occurred at depths of 50-75 m (medium silt) and 2% at 150->175 m (medium silt).

Cyclocardia crebricostata was distributed primarily on the inner, southern portion of the southeastern shelf with a small pocket of individuals north of the Pribilof Islands (Figs. 2.1, 2.14, 2.15). The greatest abundance of this species occurred at Stations 1, 10, 11, 20, 23, and 55 (Figs. 2.14, 2.15; Appendices 2.A, 2.B). The species was present at 25% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 1, 6, 20, 24, 55 and 60 (Appendix 2.C). *Cyclocardia crebricostata* was associated with sediments ranging from very coarse sand to coarse silt (-0.77-4.8ϕ: Tables 2.I, 2.II; Figs. 2.2-2.6, 2.14, 2.15, 2.16; Table 2.III). Major Component of Collection: Seventy-six percent (76%) of

TABLE 2.IV

PERCENTAGE OF PELECYPOD SPECIES BY SEDIMENT SORTING VALUES BASED ON SOUTHEASTERN BERING SEA GRAB DATA 1975

(Based on counts/meter squared)

Sort Values

Species	<.35	.35-.5	>.5-.71	>.71-1	>1-2	>2-4	4-10
Nucula tenuis	3	4	0	8	75	10	0
Nuculana fossa	0	0	0	2	96	3	0
Yoldia amygdalea	0	3	0	1	89	7	0
Macoma calcarea	1	0	1	0	98	0	0
Tellina lutea	3	39	11	1	44	2	0
Clinocardium ciliatum	0	0	0	0	100	0	0
Cyclocardia crebricostata	0	8	13	58	20	1	0
Spisula polynyma	5	0	32	1	59	3	0

TABLE 2.V

PERCENTAGE OF PELECYPOD SPECIES BY DEPTH, BASED ON SOUTHEASTERN BERING SEA GRAB DATA 1975

(Based on counts/meter squared)

Depths in Percentages

Species	0-25	25-50	50-75	75-100	100-125	125-150	150-175
Nucula tenuis	1	1	52	40	2	4	0
Nuculana fossa	0	0	4	70	24	0	2
Yoldia amygdalea	0	0	28	64	7	0	1
Macoma calcarea	0	1	32	65	2	0	0
Tellina lutea	40	38	22	0	0	0	0
Clinocardium ciliatum	0	0	97	2	1	0	0
Cyclocardia crebricostata	1	53	46	0	0	0	0
Spisula polynyma	1	5	49	45	0	0	0

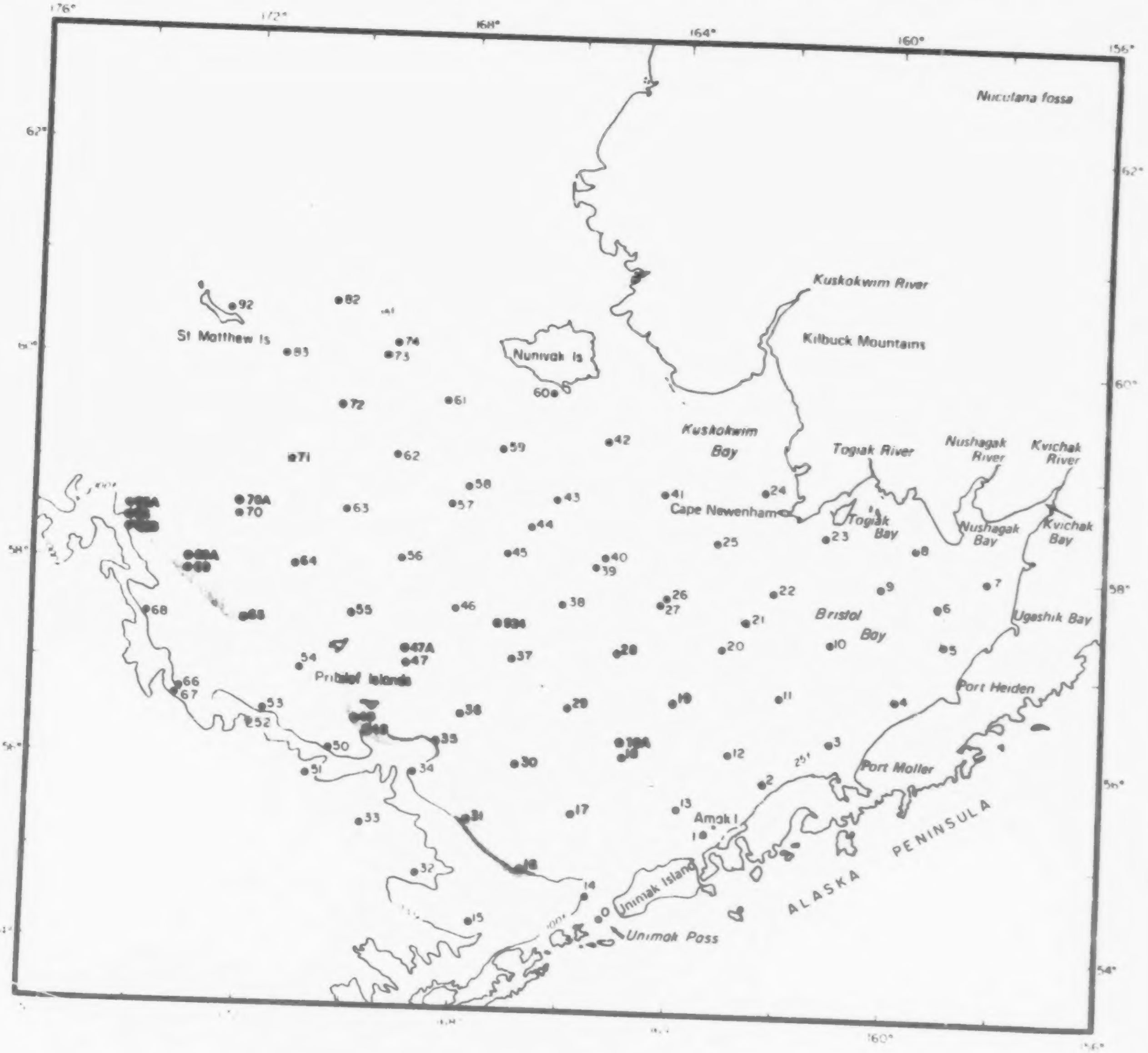

Nuculana fossa
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
St Matthew Is
Nunivak Is
Kuskokwim River
Kilbuck Mountains
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
61
60
71
62
59
42
70A
70
63
58
57
43
41
24
44
25
23
8
64
56
45
40
39
68
65
55
46
38
26
27
22
9
7
21
6
54
47A
47
37
28
20
10
5
66
67
53
52
36
29
19
11
4
50
51
35
34
30
18A
18
12
3
2
33
31
17
13
1
32
16
14
15

Figure 2.11. Distribution of *Nuculana fossa* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

BEST DOCUMENT AVAILABLE

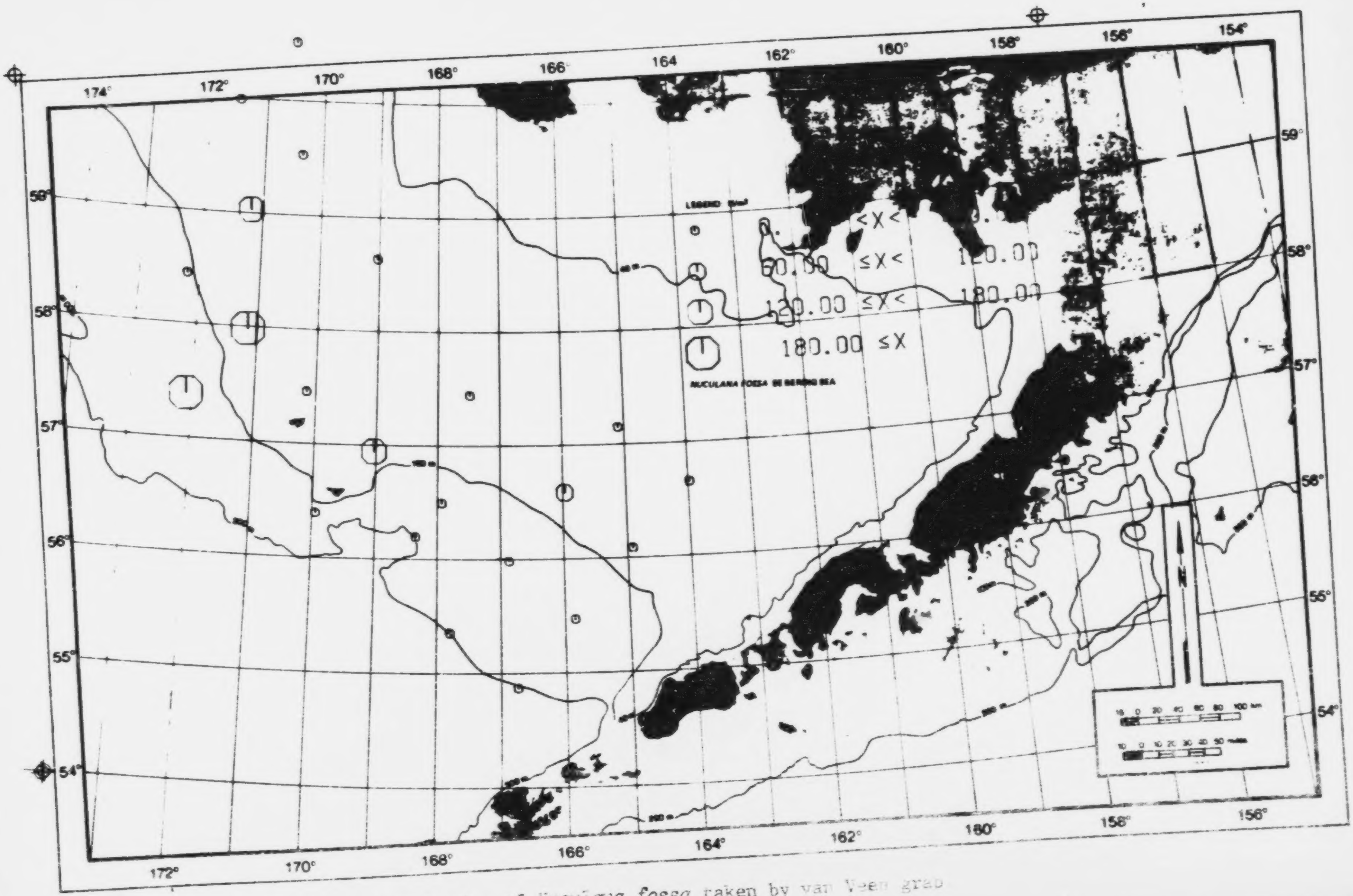
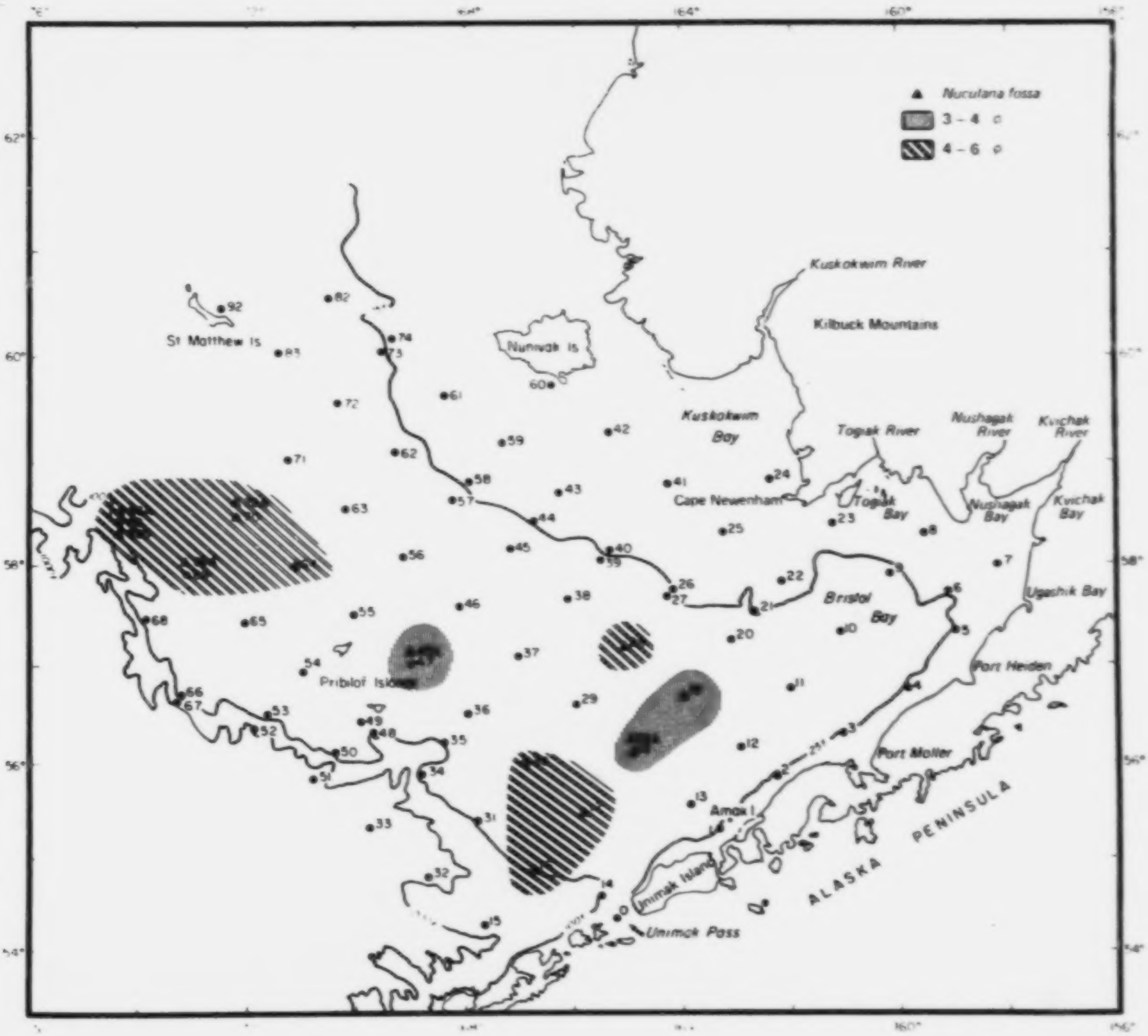

LEGEND
<X<
60.00 ≤X< 120.00
120.00 ≤X< 180.00
180.00 ≤X
NUCULANA FOSSA SE BERING SEA
174°
172°
170°
168°
166°
164°
162°
160°
158°
156°
154°
59°
58°
57°
56°
55°
54°
0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
N

Figure 2.12. Quantitative distribution of *Nuculana fossa* taken by van Veen grab.



Nuculana fossa
3 – 4 φ
4 – 6 φ
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
62°
60°
58°
56°
54°
164°
160°
92
82
83
74
73
72
61
60
42
59
62
71
58
57
41
24
43
63
44
25
23
8
56
45
40
39
26
27
22
9
7
6
46
38
21
68
65
55
20
10
5
54
37
4
66
67
29
11
53
36
49
48
35
12
52
50
34
3
2
51
13
31
33
32
14
15

Figure 2.13. Distribution of *Nuculana fossa* collected by pipe dredge and phi values associated with the clam distribution.

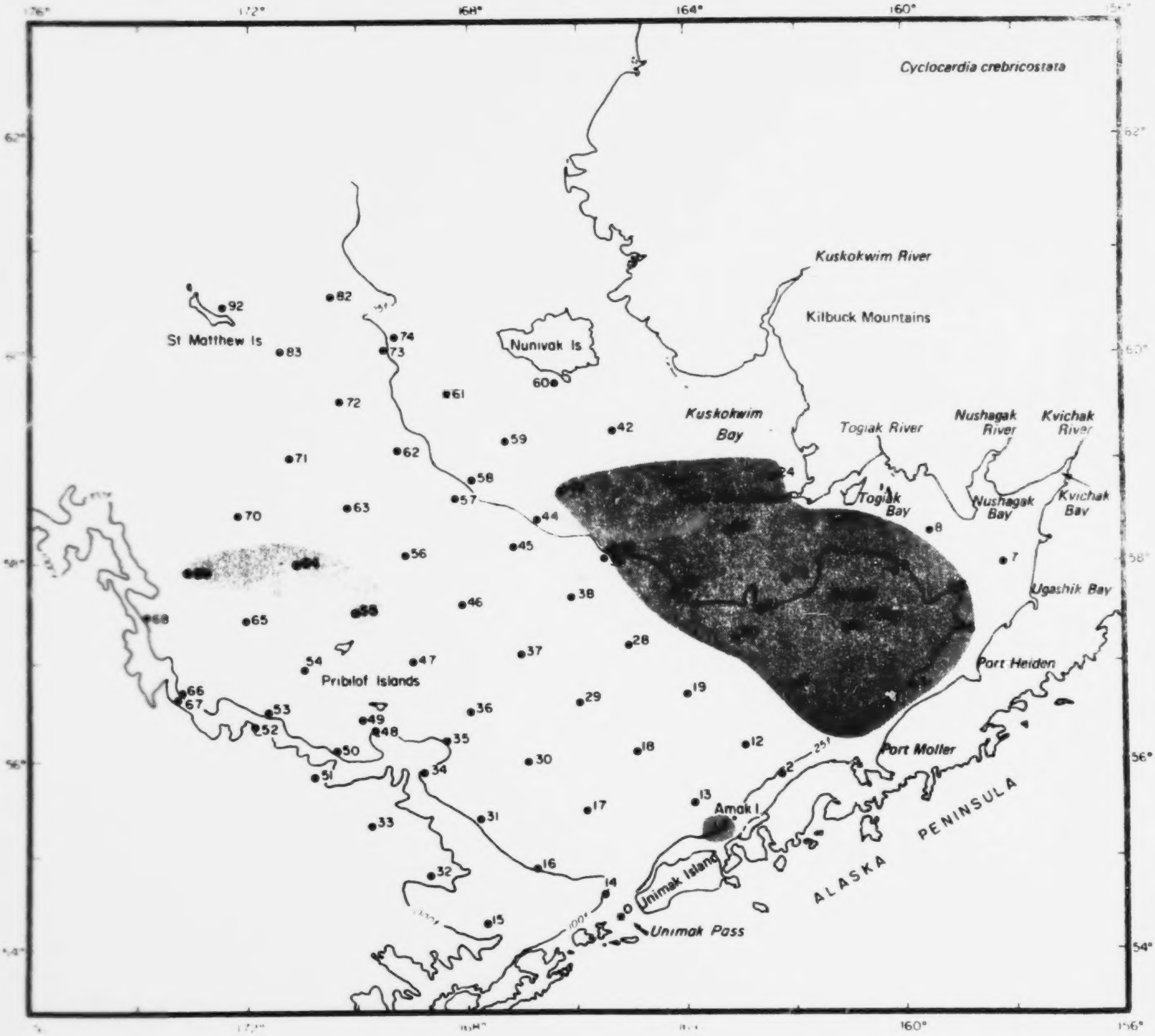

Cyclocardia crebricostata
176°
172°
168°
164°
160°
62°
60°
58°
56°
54°
156°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
74
73
83
72
61
60
71
62
59
42
24
58
57
63
70
44
45
56
8
7
38
46
65
68
28
37
47
54
19
29
66
67
36
53
49
52
48
35
12
18
50
30
34
51
13
17
31
33
16
32
14
15
2
25
100

Figure 2.14. Distribution of *Cyclocardia crebricostata* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

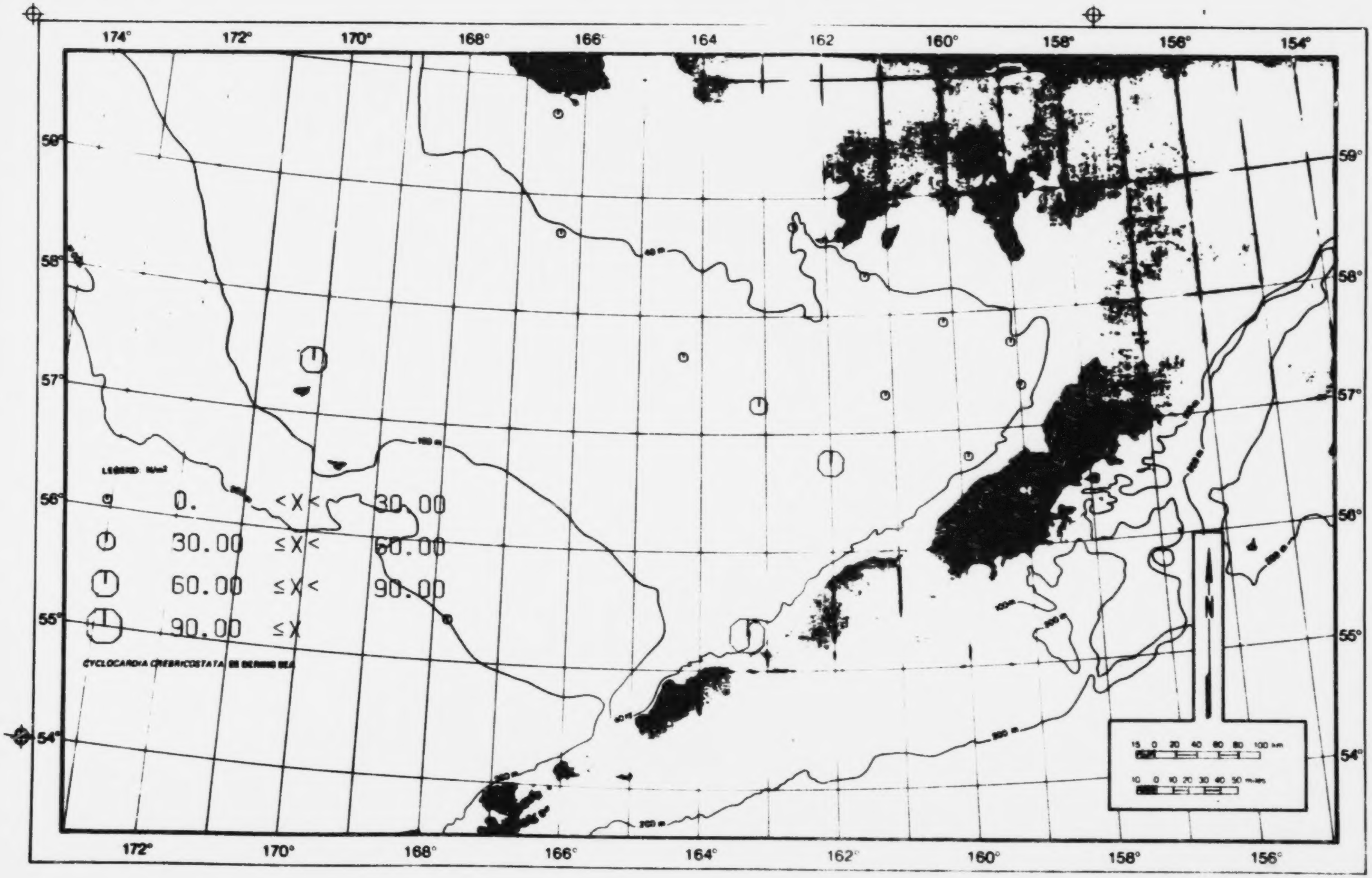
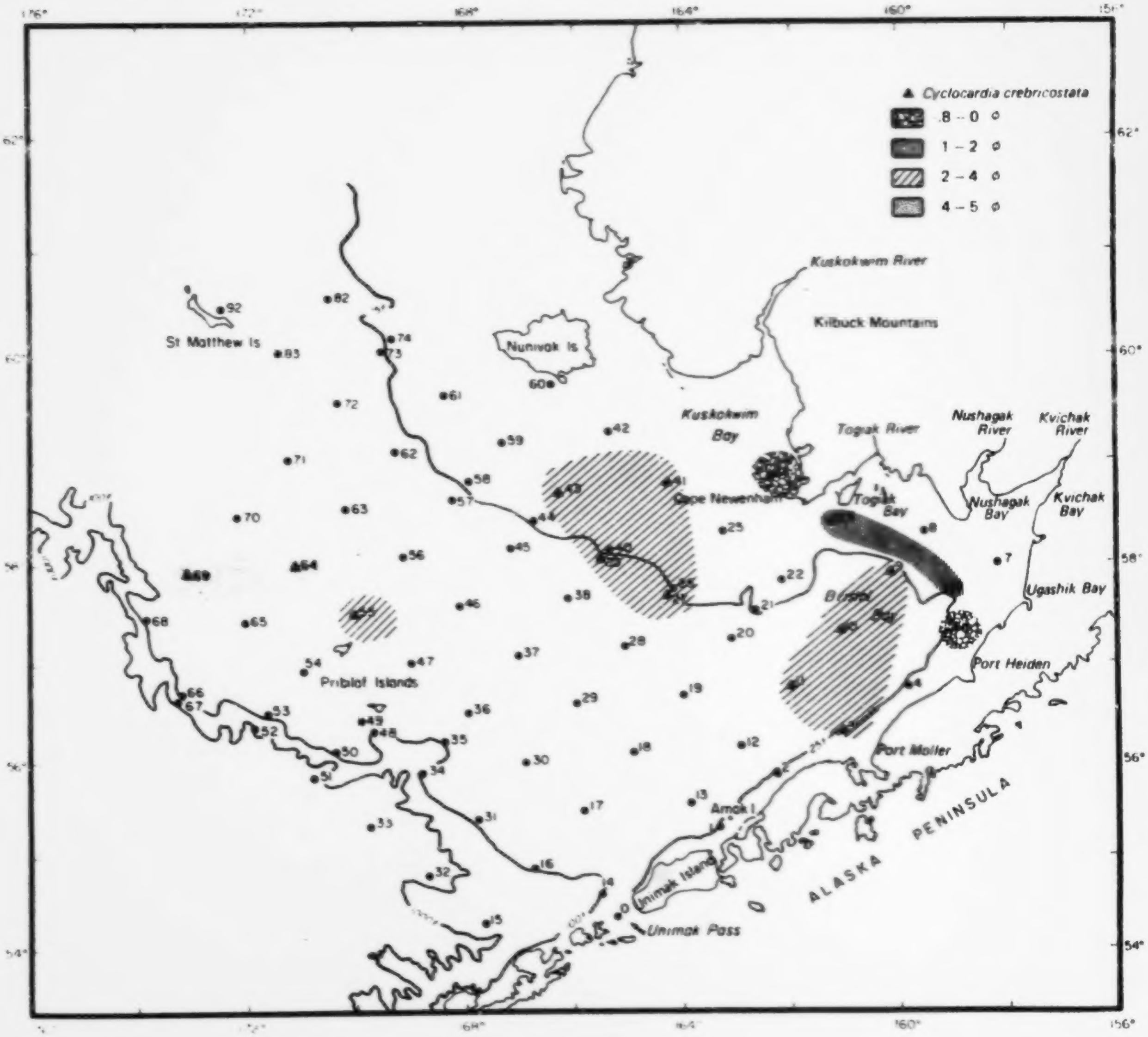

174°
172°
170°
168°
166°
164°
162
160°
158°
156°
154°
59°
58°
57°
56°
55°
54°
100 m
200 m
LEGEND: N/m²
0. <X< 30.00
30.00 ≤X< 60.00
60.00 ≤X< 90.00
90.00 ≤X
CYCLOCARDIA CREBRICOSTATA IN BERING SEA
N
15 0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
172°
170°
168°
166°
164°
162°
160°
158°
156°

Figure 2.15. Quantitative distribution of *Cyclocardia crebricostata* taken by van Veen grab.



▲ Cyclocardia crebricostata
-.8 – 0 ϕ
1 – 2 ϕ
2 – 4 ϕ
4 – 5 ϕ
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 2.16. Distribution of *Cyclocardia crebricostata* collected by pipe dredge and phi values associated with the clam distribution.

C. crebricostata occurred in fine sand to very fine sand (3.0-4.0ϕ) with 58% of the clams at sediment sorting values from >.71-1.0 (Table 2.IV). Ninety-nine percent (99%) of *C. crebricostata* occurred from 25-75 m (Table 2.V; Appendix 2.D). Minor Component of Collection: Five percent (5%) of the clams occurred in coarse to medium sand (1.0-2.0ϕ), 18% in medium to fine sand (2.0-3.0ϕ) and 1% in coarse sand to medium silt (4.8-5.0ϕ) with 8% of the sediment sorting at .35-5, 13% at >.5-.71, 20% at >1.0-2.0 and 1% at >2.0-4.0. One percent (1%) of *C. crebricostata* occurred at depths of <25 m (coarse sand).

Macoma calcarea was mainly distributed on the southern portion of the southeastern shelf but extended north and west into the central and outer shelf (Figs. 2.1, 2.17, 2.18). The greatest abundance of this species occurred at Stations 10, 12, 28, 45, 63, 64, 65, 71, 70A and 83 (Figs. 2.1, 2.17, 2.18; Appendices 2.A, 2.B). The species was present at 23% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 10, 22, 45, 63 and 64 (Appendix 2.C). *Macoma calcarea* was associated with sediments types ranging from medium sand to medium silt (2.0-5.7ϕ; Tables 2.I, 2.II; Figs. 2.2-2.6, 2.17, 2.18, 2.19; Table 2.III). Major Component of Collection: Ninety-four percent (94%) of *M. calcarea* occurred in very fine sand to medium silt (4.25-5.7ϕ) with 98% of the clams at sediment sorting values from >1.0-2.0 (Table 2.IV). Ninety-seven percent (97%) of *M. calcarea* occurred from 50-100 m (Table 2.V; Appendix 2.D). Minor Component of Collection: Two percent (2%) of the clams occurred in medium to fine sand (2.0-3.0ϕ) and 4% at fine to very fine sand (3.0-4.0ϕ) with 1% of the species at sediment sorting values of <.35 and 1% at >.51-.71. Three percent (3%) of *M. calcarea* occurred at depths of 100-125 m (fine to very fine sand).

Clinocardium ciliatum was present on the southern, outer portion of the southeastern shelf and extended north along the outer portion of the southeastern shelf extending somewhat into the outer shelf (Figs. 2.1, 2.20, 2.21). The greatest abundance of this species occurred at Stations 18, 28, 47, 47A and 49 (Figs. 2.20, 2.21; Appendices 2.A, 2.B). The species was present at 21% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 28, 29, and 47 (Appendix 2.C).

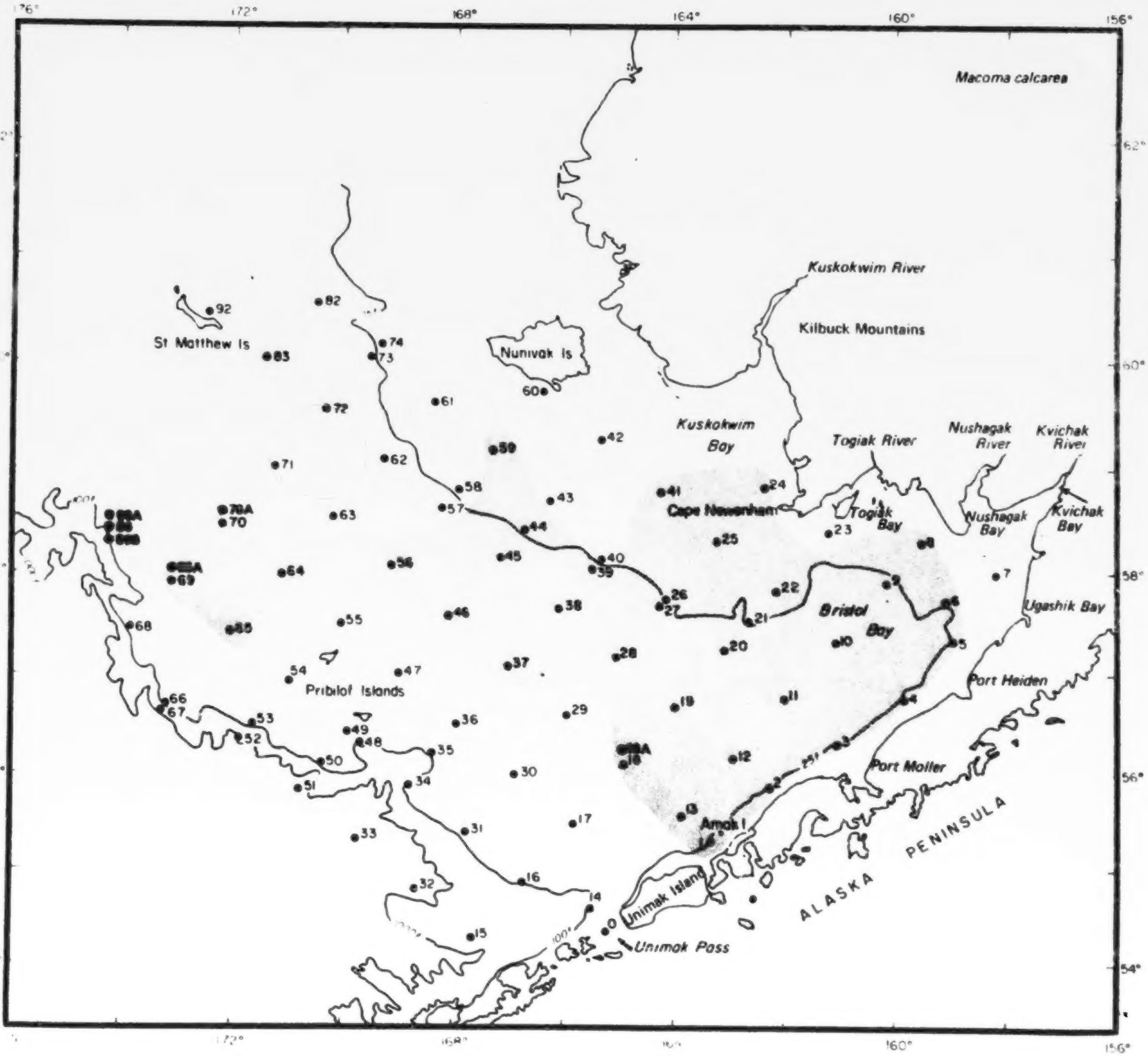

Macoma calcarea
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 2.17. Distribution of *Macoma calcarea* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

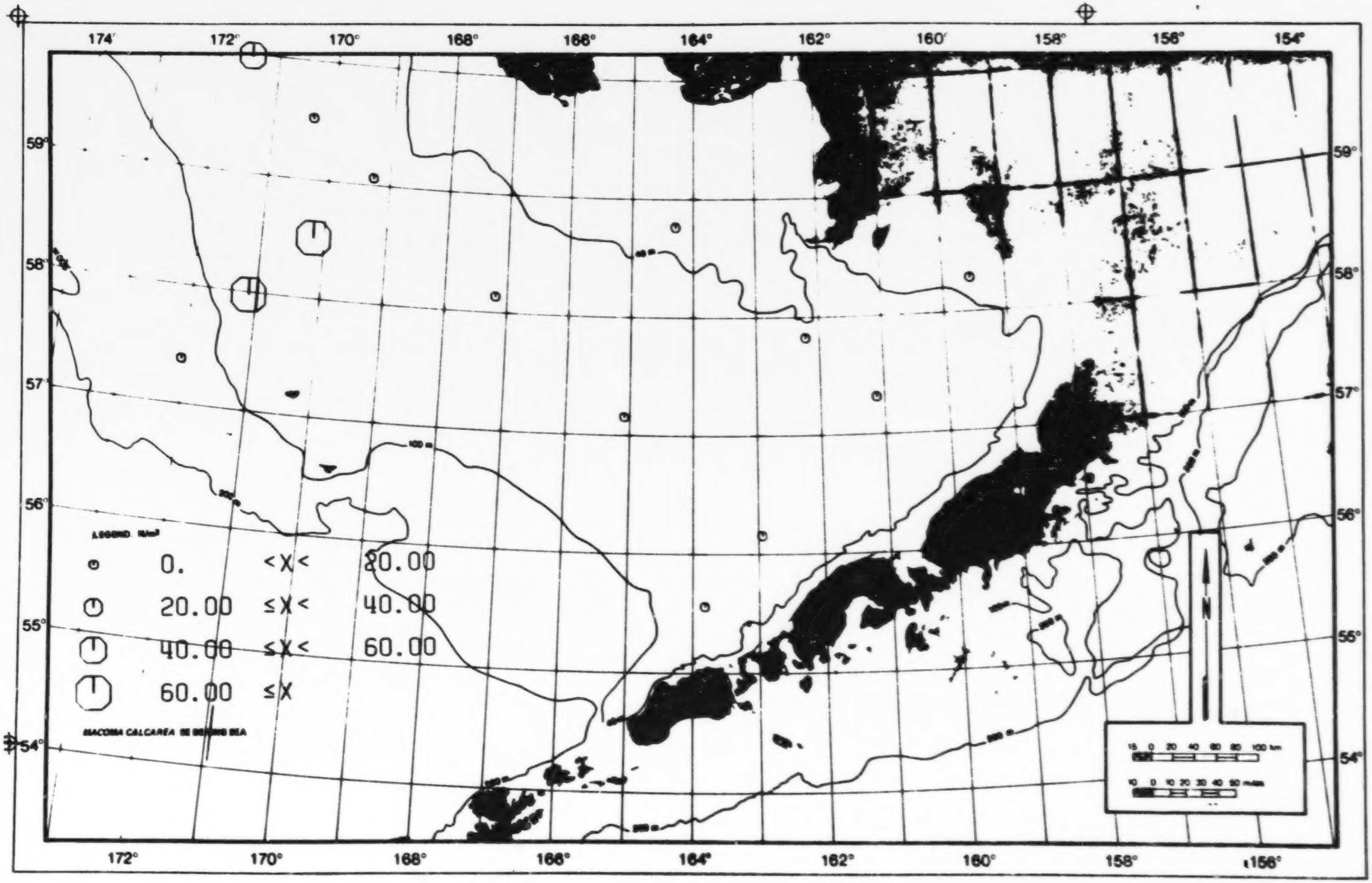

174°
172°
170°
168°
166°
164°
162°
160°
158°
156°
154°
59°
58°
57°
56°
55°
54°
LEGEND
0. <X< 20.00
20.00 ≤X< 40.00
40.00 ≤X< 60.00
60.00 ≤X
MACOMA CALCAREA SE BERING SEA
N
172°
170°
168°
166°
164°
162°
160°
158°
156°

Figure 2.18. Quantitative distribution of *Macoma calcarea* taken by van Veen grab.

439

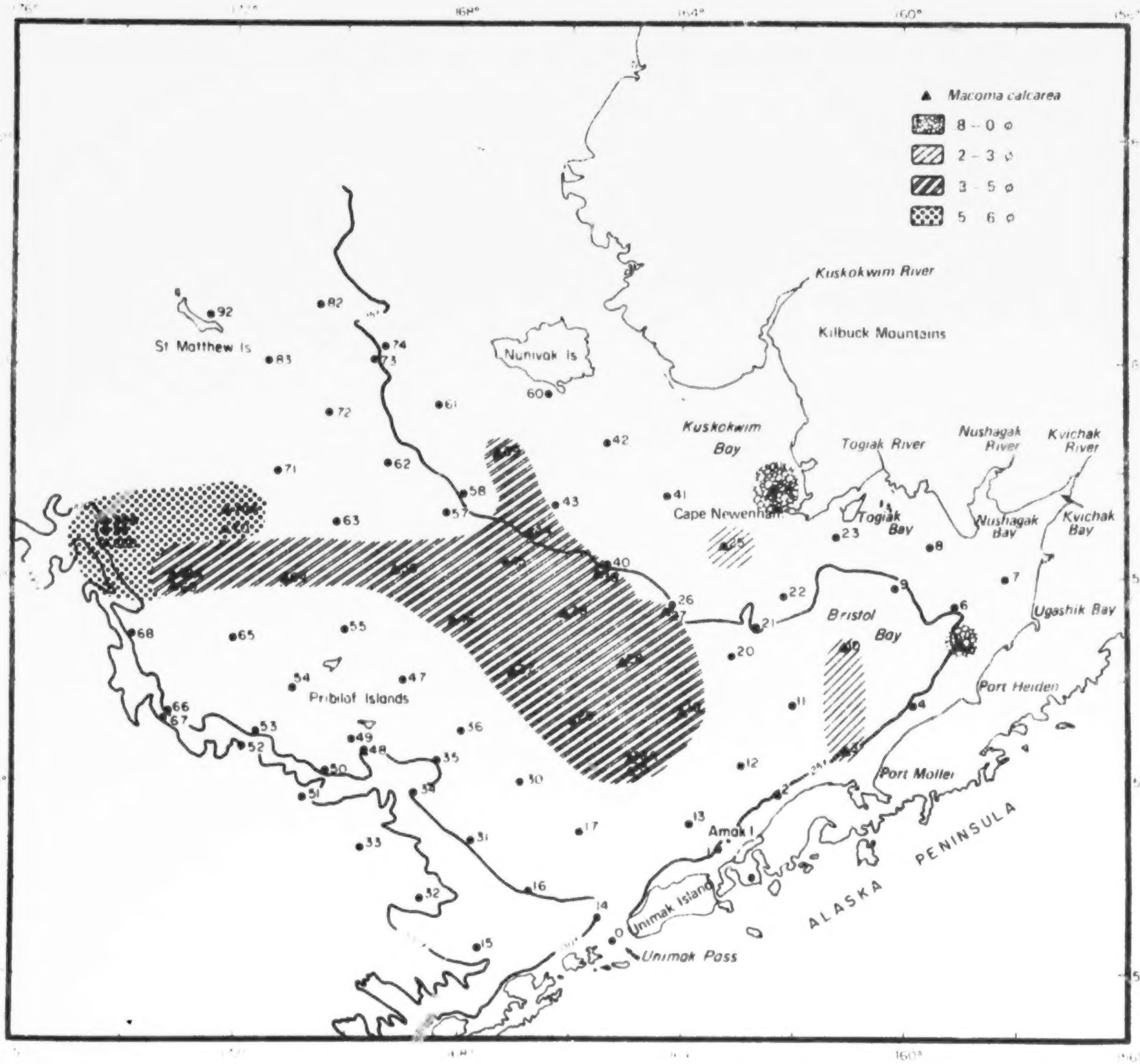

168°
160°
58°
56°
54°
▲ Macoma calcarea
.8 – 0 φ
2 – 3 φ
3 – 5 φ
5 – 6 φ
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Togiak Bay
Nushagak River
Nushagak Bay
Kvichak River
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
61
60
42
71
62
58
57
43
41
63
23
8
40
26
22
9
6
7
68
65
55
21
20
54
47
11
4
66
67
53
52
36
49
48
35
12
50
30
51
34
17
13
33
31
16
32
14
15
0

Figure 2.19. Distribution of *Macoma calcarea* collected by pipe dredge, and phi values ascociated with the clam distribution.

BEST DOCUMENT AVAILABLE

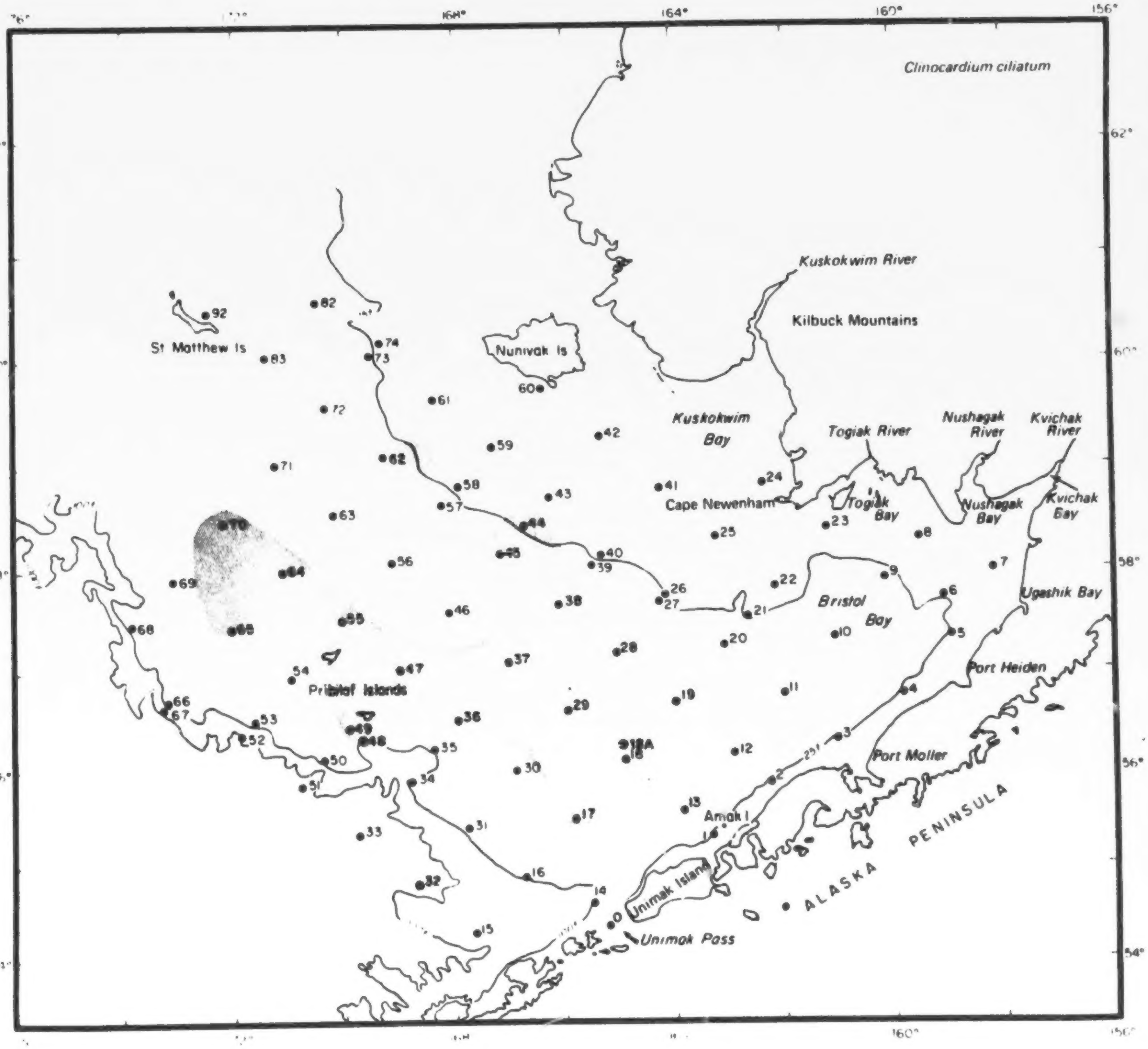

Clinocardium ciliatum
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
61
60
71
62
59
42
58
57
43
41
24
63
44
25
23
8
70
45
40
39
56
64
7
69
9
22
26
27
6
21
46
38
65
68
10
5
20
28
37
54
47
11
4
19
29
66
67
53
36
52
49
48
35
3
12
18A
18
50
30
51
34
2
13
17
31
33
16
32
14
15

Figure 2.20. Distribution of *Clinocardium ciliatum* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

BEST DOCUMENT AVAILABLE

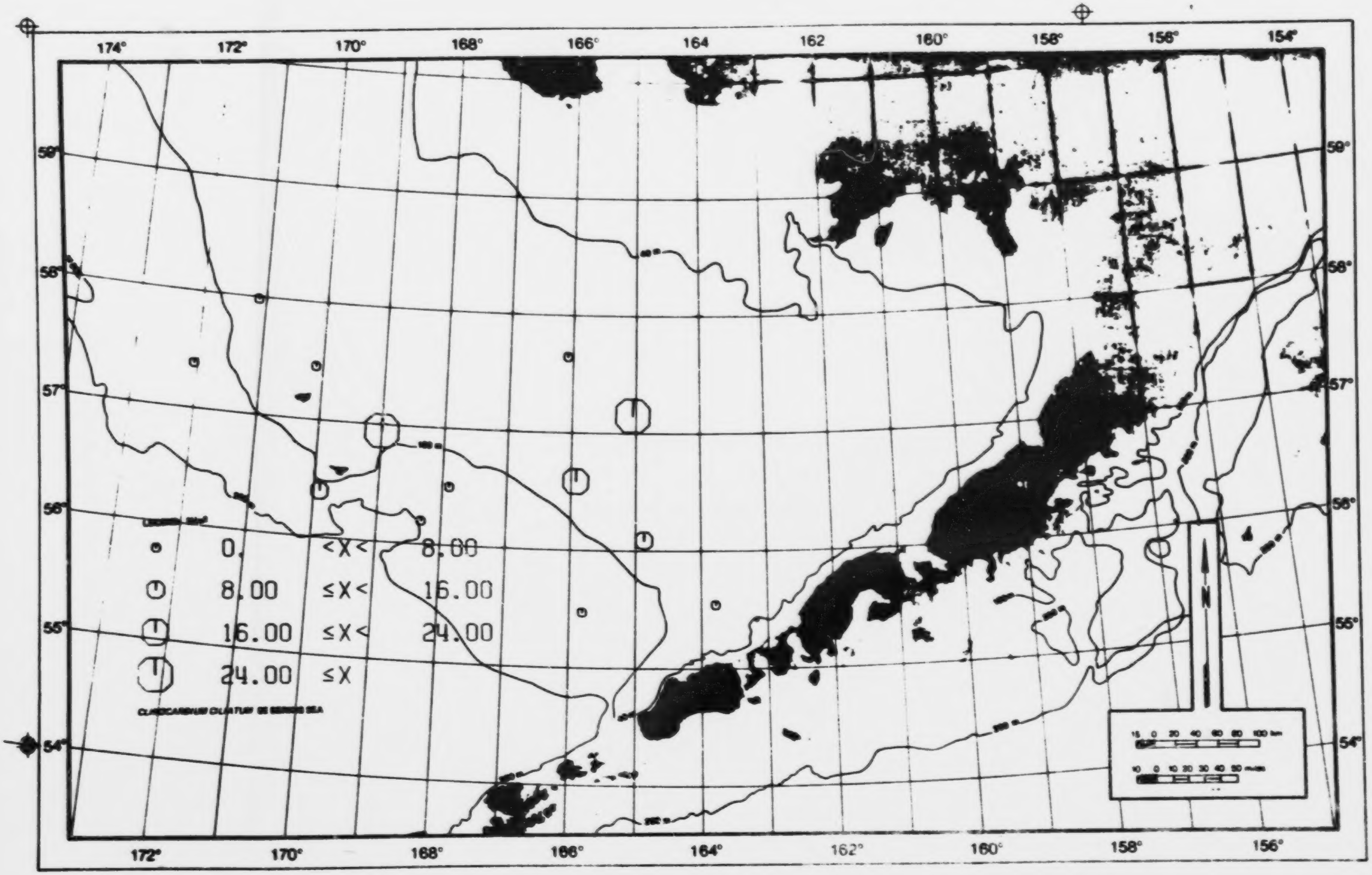

174°
172°
170°
168°
166°
164
162
160°
158°
156°
154°
59°
58°
57°
56°
55°
54°
0. <X< 8.00
8.00 ≤X< 16.00
16.00 ≤X< 24.00
24.00 ≤X
CLINOCARDIUM CILIATUM SE BERING SEA
N
172°
170°
168°
166°
164°
162°
160°
158°
156°

Figure 2.21. Quantitative distribution of *Clinocardium ciliatum* taken by van Veen grab.

Clinocardium ciliatum was associated with sediment types ranging from fine sand to medium silt (3.4-5.7ϕ; Tables 2.I, 2.II; Figs. 2.2-2.6, 2.20, 2.21, 2.22; Table 2.III). Major Component of Collection: Ninety-eight percent (98%) of *C. ciliatum* occurred in very fine sand to medium silt (3.4-5.0ϕ) with 100% of the clams at sediment sorting values from >1.0-2.0 (Table 2.IV). Ninety-seven percent (97%) of *C. ciliatum* occurred from 50-75 m (Table 2.V; Appendix 2.D). Minor Component of Collection: One percent (1%) of the clams occurred in fine to very fine sand (3.0-4.0ϕ) and 1% in medium silt (5.0-5.7ϕ; Table 2.II). Two percent (2%) of *C. ciliatum* occurred at depths of 75-100 m and 1% at 100-125 m (medium silt).

Yoldia amygdalea was present on the central, southern and northern portions of the southeastern shelf and extended north and south along the outer portion of the southeastern shelf extending into the outer and central shelves (Figs. 2.1, 2.23, 2.24). The greatest abundance of this species occurred at Stations 63, 64, 70, 70A, 71 and 72 (Figs. 2.23, 2.24; Appendices 2.A, 2.B). The species was present at 23% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 63, 64, 70, 71, 72, 82, 83, and 937 (Appendix 2.C). *Y. amygdalea* was associated with sediment types ranging from medium sand to medium silt (2.0-5.7ϕ; Tables 2.I, 2.II; Figs. 2.2-2.6, 2.23, 2.24, 2.25; Table 2.III). Major Component of Collection: Eighty-nine percent (89%) of *Y. amygdalea* occurred in very fine sand to medium silt (4.0-5.0ϕ) with 89% of the clams at sediment sorting values from 1.0-2.0 (Table 2.IV). Ninety-two percent (92%) of *Y. amygdalea* occurred from 50-100 m (Table 2.V; Appendix 2.D). Minor Component of Collection: One percent (1%) of the clams occurred in medium to fine sand (2.0-3.0ϕ), 3% at fine to very fine sand (3.0-4.0ϕ) and 7% at medium silt (5.7ϕ) with 3% of the species at sediment sorting values of .35-.50, 1% at >.71-1.0 and 7% at >2.0-4.0. Seven percent (7%) of *Y. amygdalea* occurred at depths of 100-125 m and 1% at >175 m (medium silt).

Tellina lutea was present on the nearshore and central portions of the southeastern shelf and extended northwest into the central shelf (Figs. 2.1, 2.26, 2.27). The greatest abundance of this species occurred at Stations 5, 8, 23, and 28 (Figs. 2.26, 2.27; Appendices 2.A, 2.B). The species was present at 28% of the stations sampled by van Veen grab (Appendix 2.A).

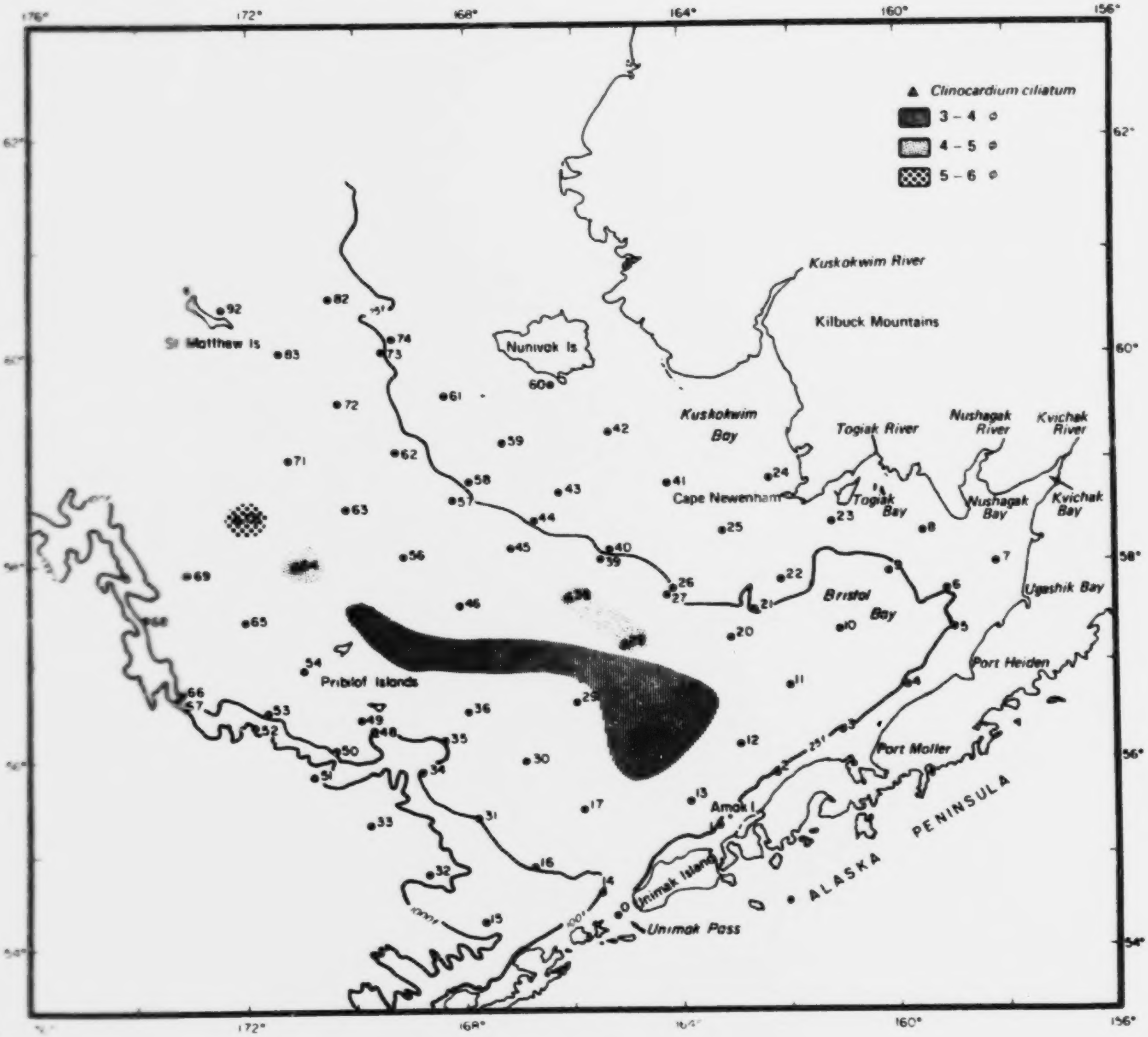

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
▲ Clinocardium ciliatum
■ 3 – 4 φ
▨ 4 – 5 φ
▩ 5 – 6 φ
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I.
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
71
61
60
62
59
42
41
24
58
57
43
63
44
25
23
8
56
45
40
39
22
7
69
26
27
21
46
10
6
65
20
5
54
11
4
66
67
53
36
29
49
52
48
35
3
12
50
34
30
51
17
13
31
33
16
32
14
15
0
100f
25f

Figure 2.22. Distribution of *Clinocardium ciliatum* collected by pipe dredge, and phi values associated with the clam distribution.

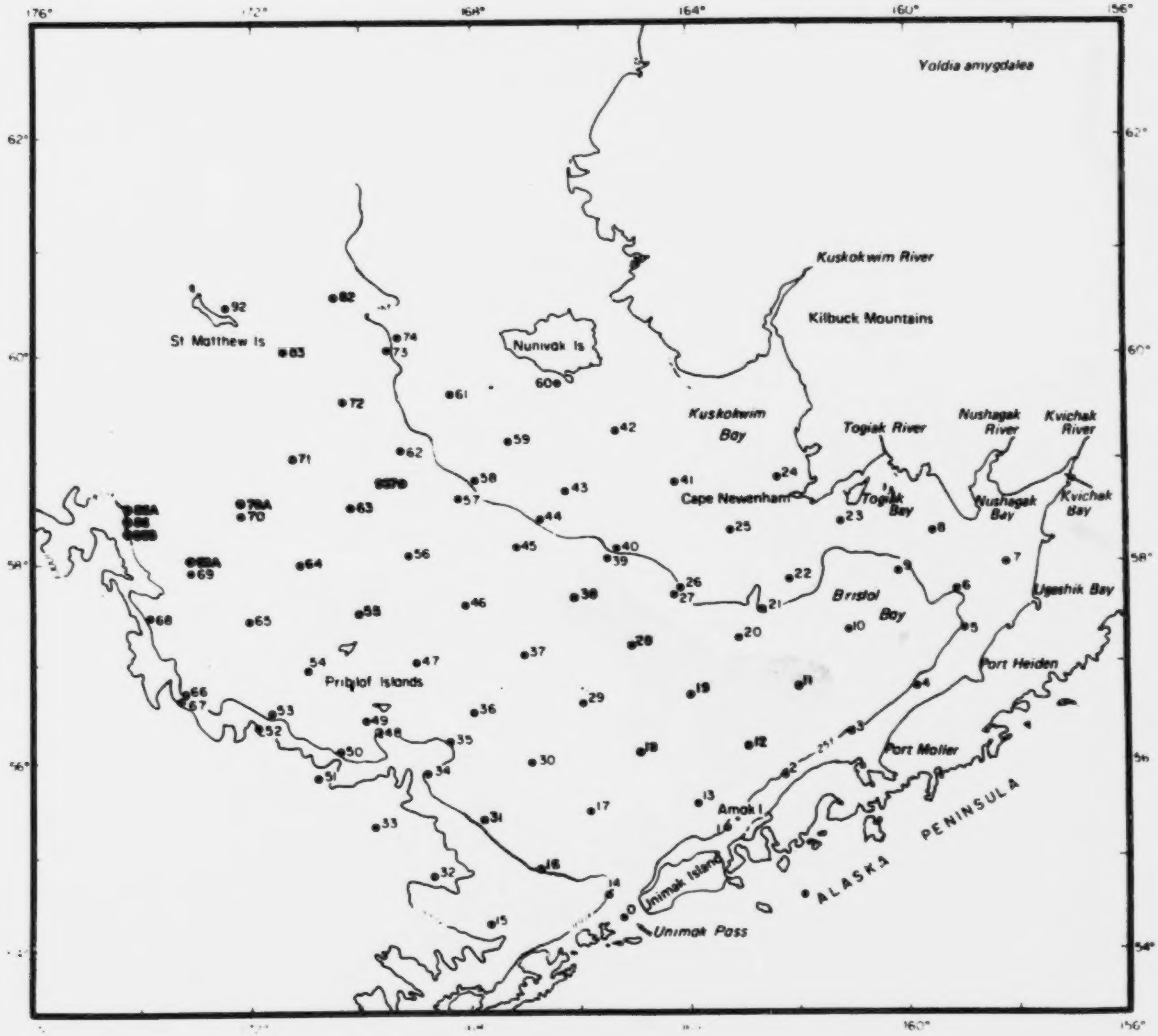

Yoldia amygdalea
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
71
62
61
60
59
58
57
42
43
41
44
45
40
39
24
25
23
26
27
22
21
20
10
9
8
7
6
5
4
3
2
1
70A
70
63
64
69
65
68
56
55
54
47
46
38
37
36
35
29
28
19
18
17
13
12
11
16
15
14
66
67
53
52
50
51
49
48
34
33
32
31
30
0

Figure 2.23. Distribution of *Yoldia amygdalea* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

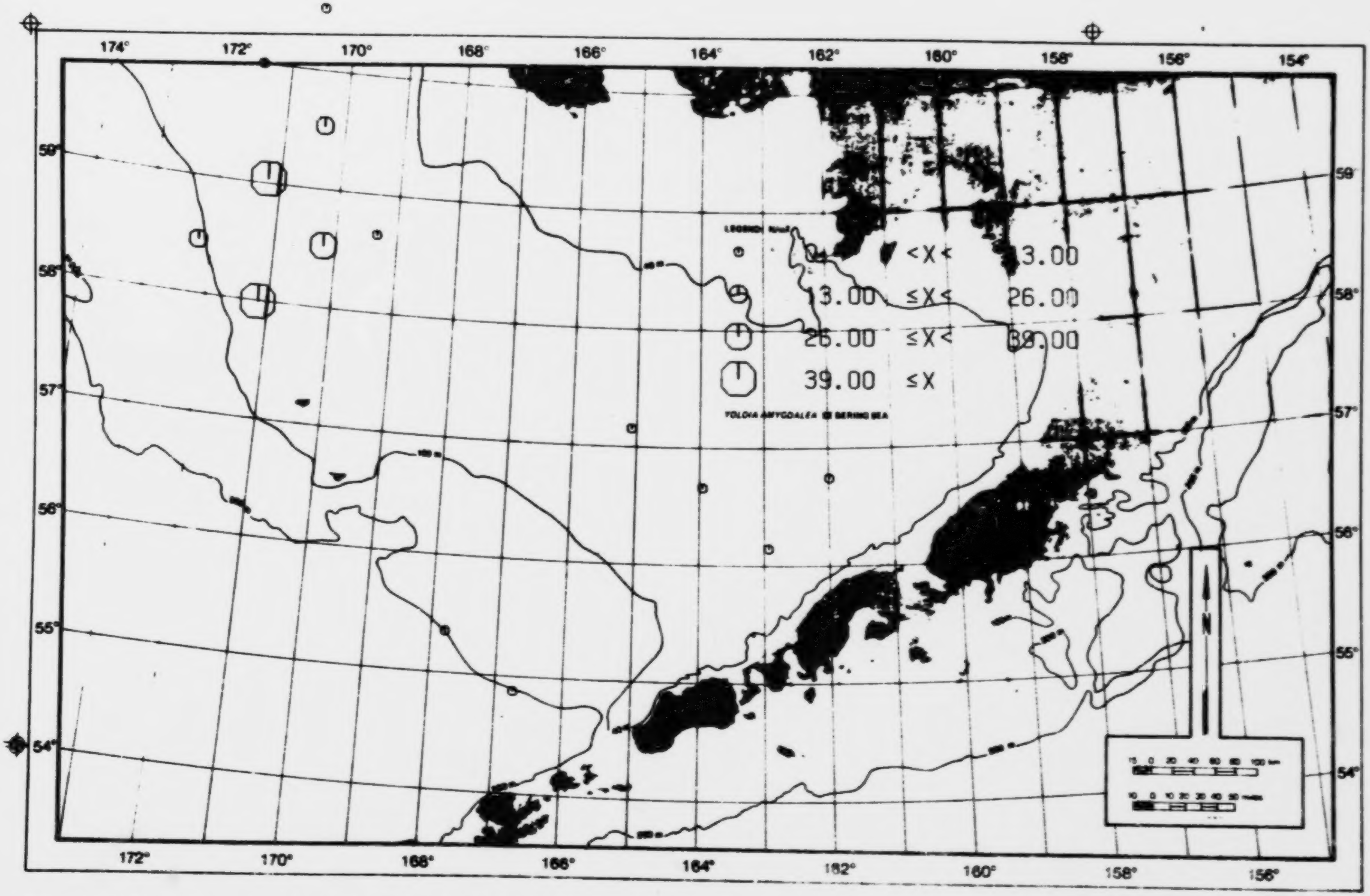
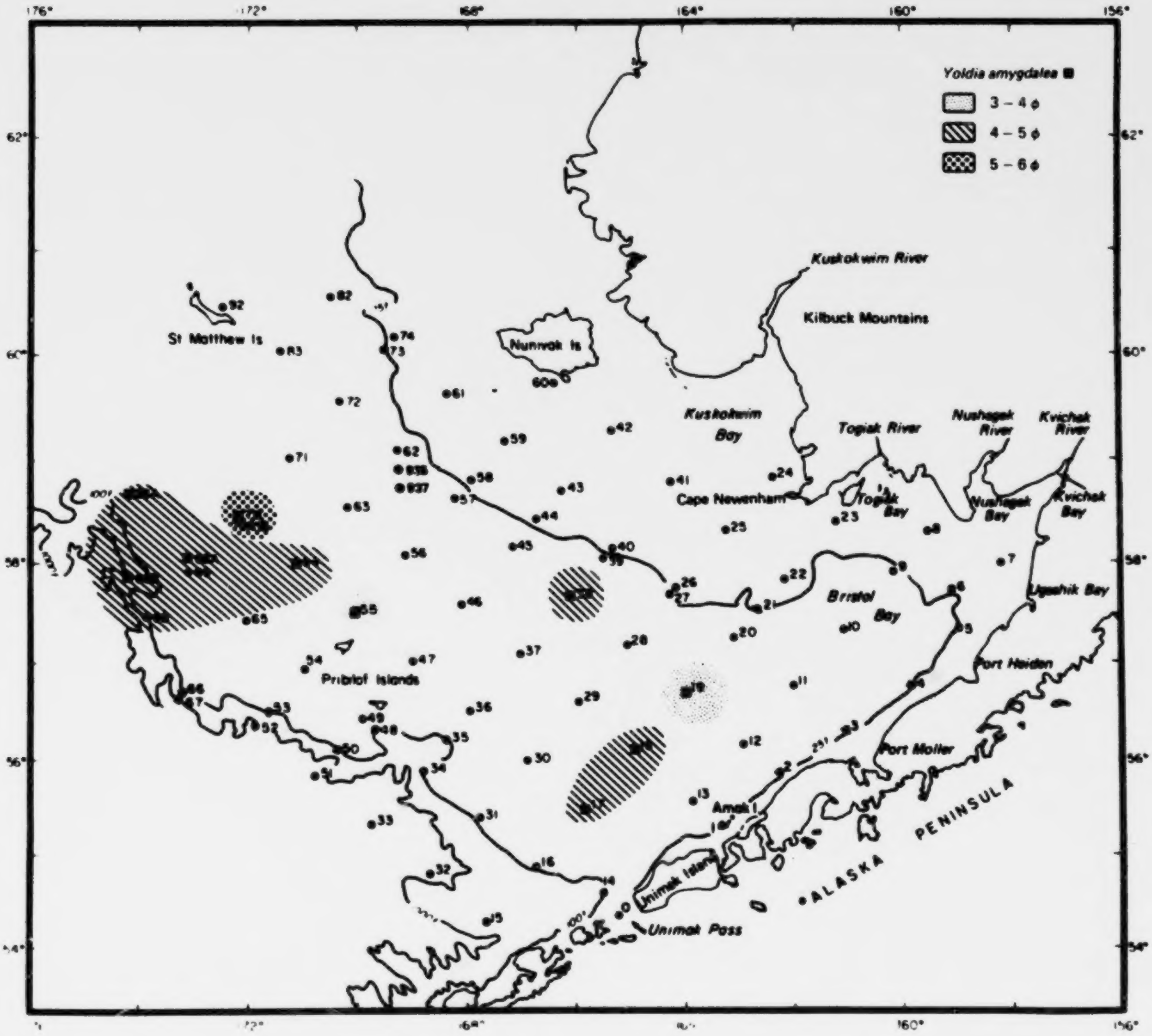

174°
172°
170°
168°
166°
164°
162°
160°
158°
156°
154°
59°
58°
57°
56°
55°
54°
LEGEND
<X<
13.00 ≤X< 26.00
26.00 ≤X< 39.00
39.00 ≤X
YOLDIA AMYGDALEA BERING SEA
N
km
miles

Figure 2.24. Quantitative distribution of *Yoldia amygdalea* taken by van Veen grab.



Yoldia amygdalea ■
3 – 4 ϕ
4 – 5 ϕ
5 – 6 ϕ
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 2.25. Distribution of *Yoldia amygdalea* collected by pipe dredge, and phi values associated with the clam distribution.

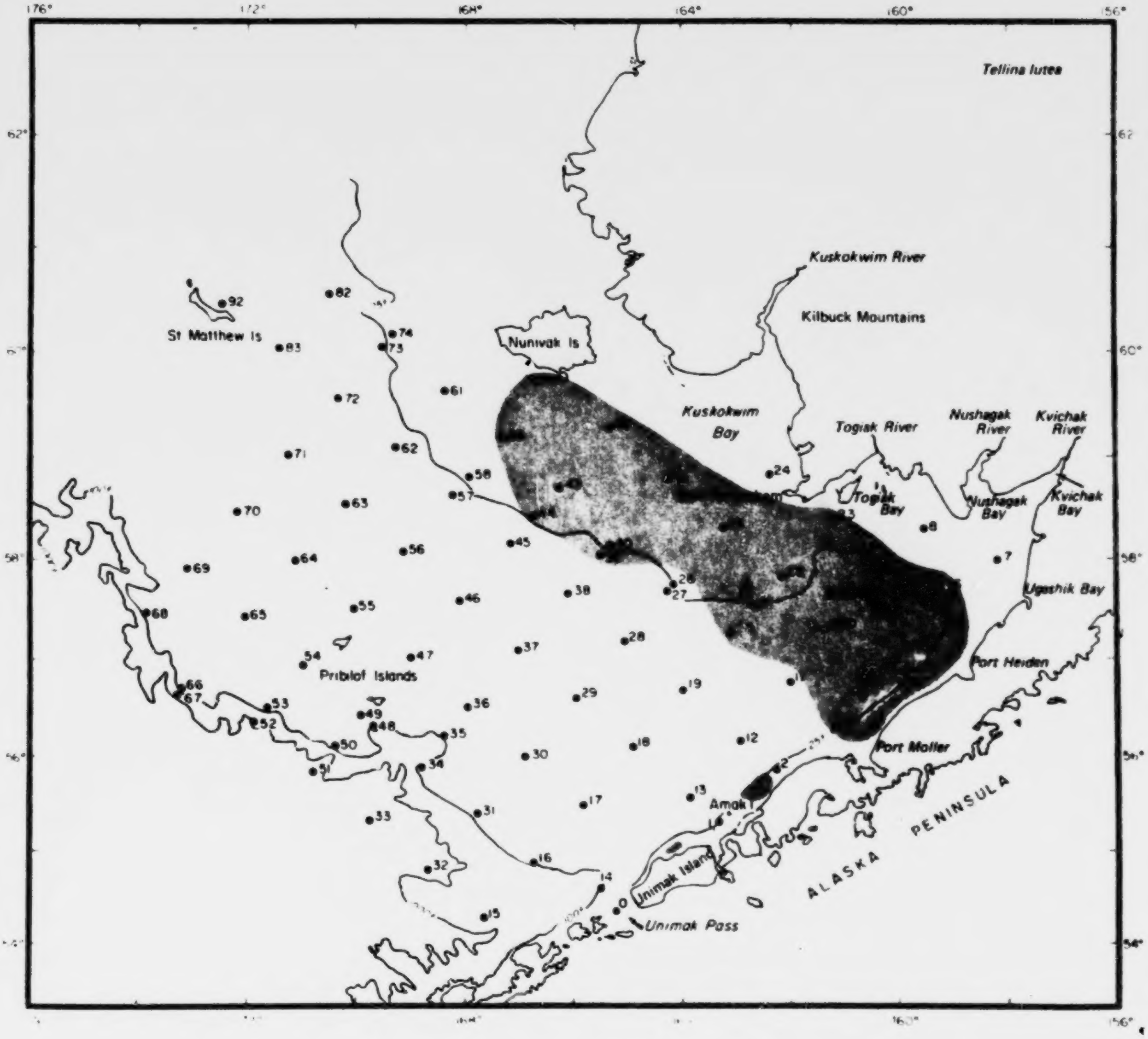

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Tellina lutea
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 2.26. Distribution of *Tellina lutea* based on collections taken with a grab, grab, pipe dredge, clam dredge and otter trawl.

BEST DOCUMENT AVAILABLE

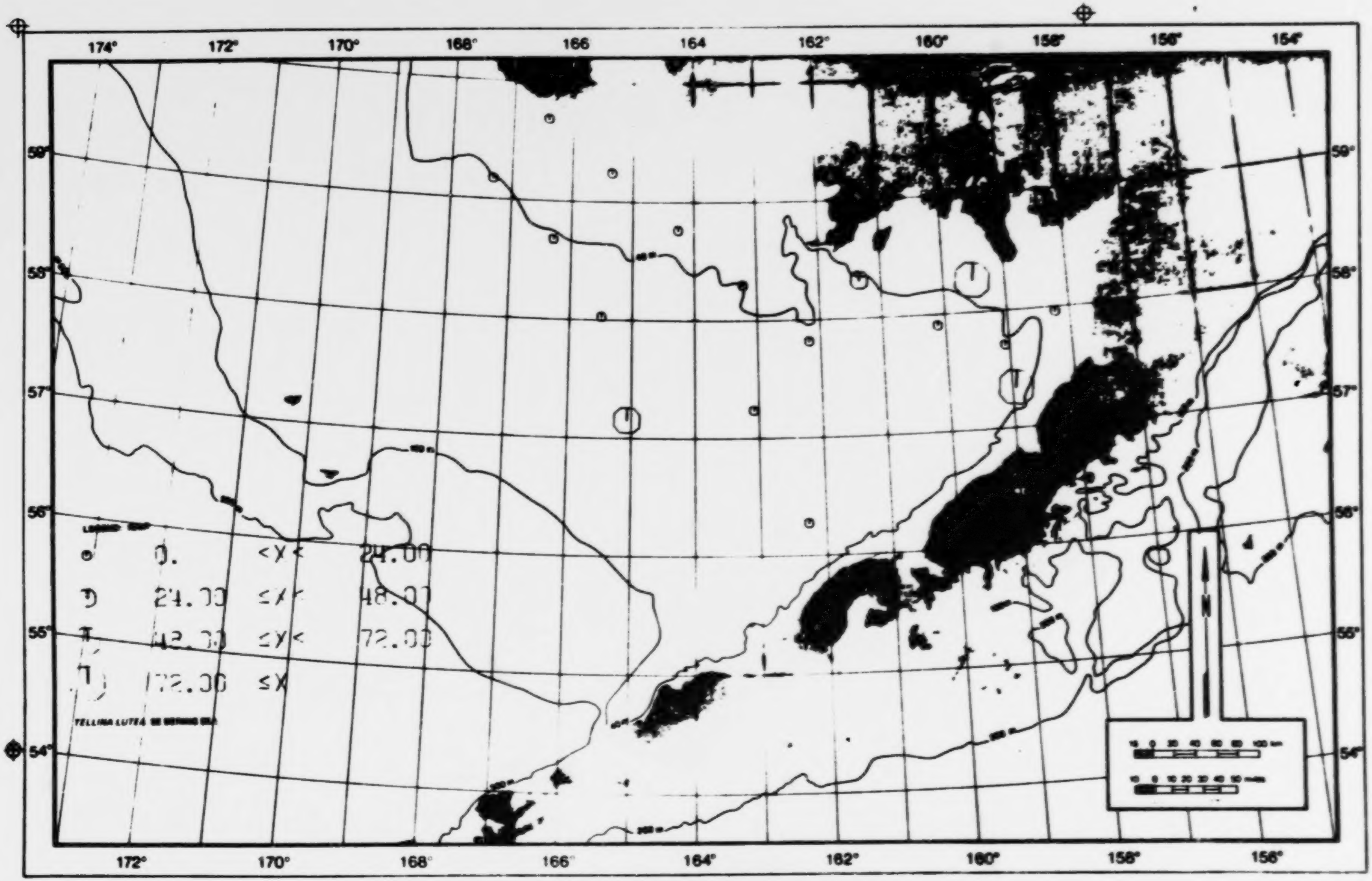

174°
172°
170°
168°
166
164
162°
160°
158°
156°
154°
59°
58°
57°
56°
55°
54°
0. <X< 24.00
24.00 ≤X< 48.00
48.00 ≤X< 72.00
72.00 ≤X
TELLINA LUTEA SE BERING SEA
N
172°
170°
168°
166°
164°
162°
160°
158°
156°

Figure 2.27. Quantitative distribution of *Tellina lutea* taken by van Veen grab.

449

The greatest biomass occurred at Stations 5, 7, 9, 22, 23, 25, 41, 59 and 60 (Appendix 2.C). *T. lutea* was associated with sediment types ranging from very coarse to medium silt (-0.77-5.0ϕ; Tables 2.I, 2.II; Figs. 2.2-2.6, 2.26, 2.27, 2.28; Table 2.III). Major Component of Collection: Seventy percent (70%) of *T. lutea* occurred in medium to fine sand (2.0-3.0ϕ) with 83% of the clams at sediment sorting values from .35-.5 (39%) and 1.0-2.0 (44%) (Table 2.IV). Seventy-eight percent (78%) of *T. lutea* occurred from <25-50 m (Table 2.V; Appendix 2.D). Minor Component of Collection: Nine percent (9%) of the clams occurred in very coarse to medium sand (0.0-2.0ϕ) and 21% in fine sand to medium silt (3.0-5.0ϕ) with 4% of the species at sediment sorting values of <.35, 12% at .5-1.0 and 2% at 2.0-4.0. Twenty-two percent (22%) of *T. lutea* occurred at depths of 50-75 m (fine sand to medium silt).

The older and larger *Spisula polynyma* were not collected quantitatively by van Veen grab, and all data discussed below refer to juvenile clams only. Some quantitative data for *S. polynyma* are included in Section 4 and Hughes *et al.* (1977). *Spisula polynyma* was broadly distributed over the southeastern Bering Sea, but was primarily found on the southeastern portion of the southeastern shelf. It also occurred southwest of Nunivak Island, northeast of the Pribilof Islands and at shallow depths off the Alaska Peninsula and Unimak Island (Figs. 2.1, 2.29). The greatest abundance for the young of the species occurred at Stations 3, 9, 25, 55, and 64 (Appendices 2.A, 2.B). The species was present at 19% of the stations sampled by van Veen grab (Appendix 2.A). The greatest biomass occurred at Stations 9, 55 and 64 (Appendix 2.C). *Spisula polynyma* was associated with sediment types ranging from medium sand to medium silt (2.0-5.0ϕ; Tables 2.I, 2.II; Figs. 2.2-2.6, 2.29; Table 2.III). Major Component of Collection: Fifty-nine percent (59%) of *S. polynyma* occurred in fine sand to medium silt (3.0-5.0ϕ) with 59% of the clams at sediment sorting values from >.1.0-2.0 (Table 2.IV). Ninety-four percent (94%) of *S. polynyma* occurred from 50-100 m (Table 2.V; Appendix 2.D). Minor Component of Collection: Forty-one percent (41%) of the clams occurred in medium to fine sand (2.0-3.0ϕ) with 5% of the species at sorting values of <.35, 33% at >.50-1.0, 3% at >2.0-4.0. Seven percent (7%) of *S. polynyma* occurred at depths of <25-50 m (medium to fine sand).

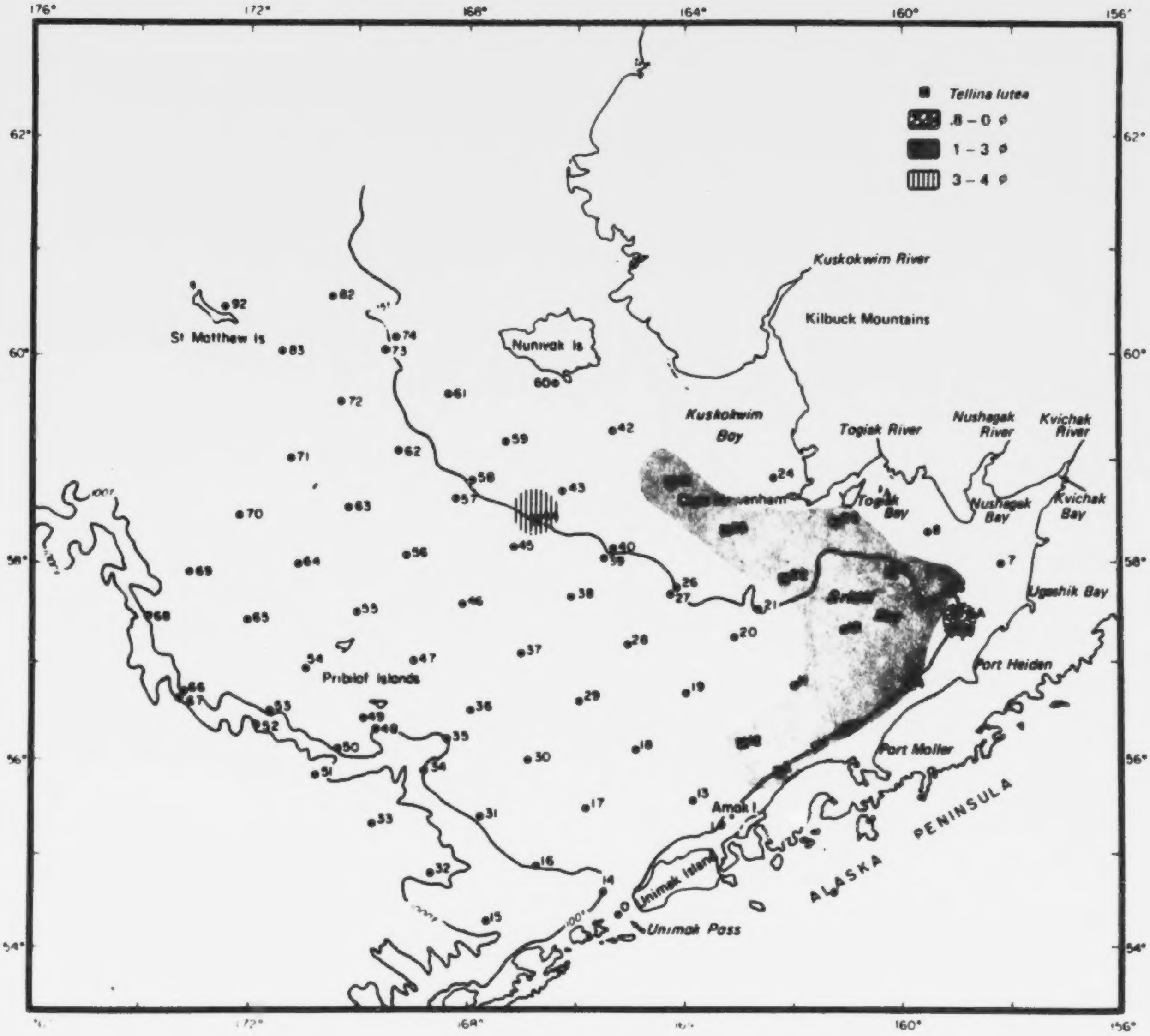
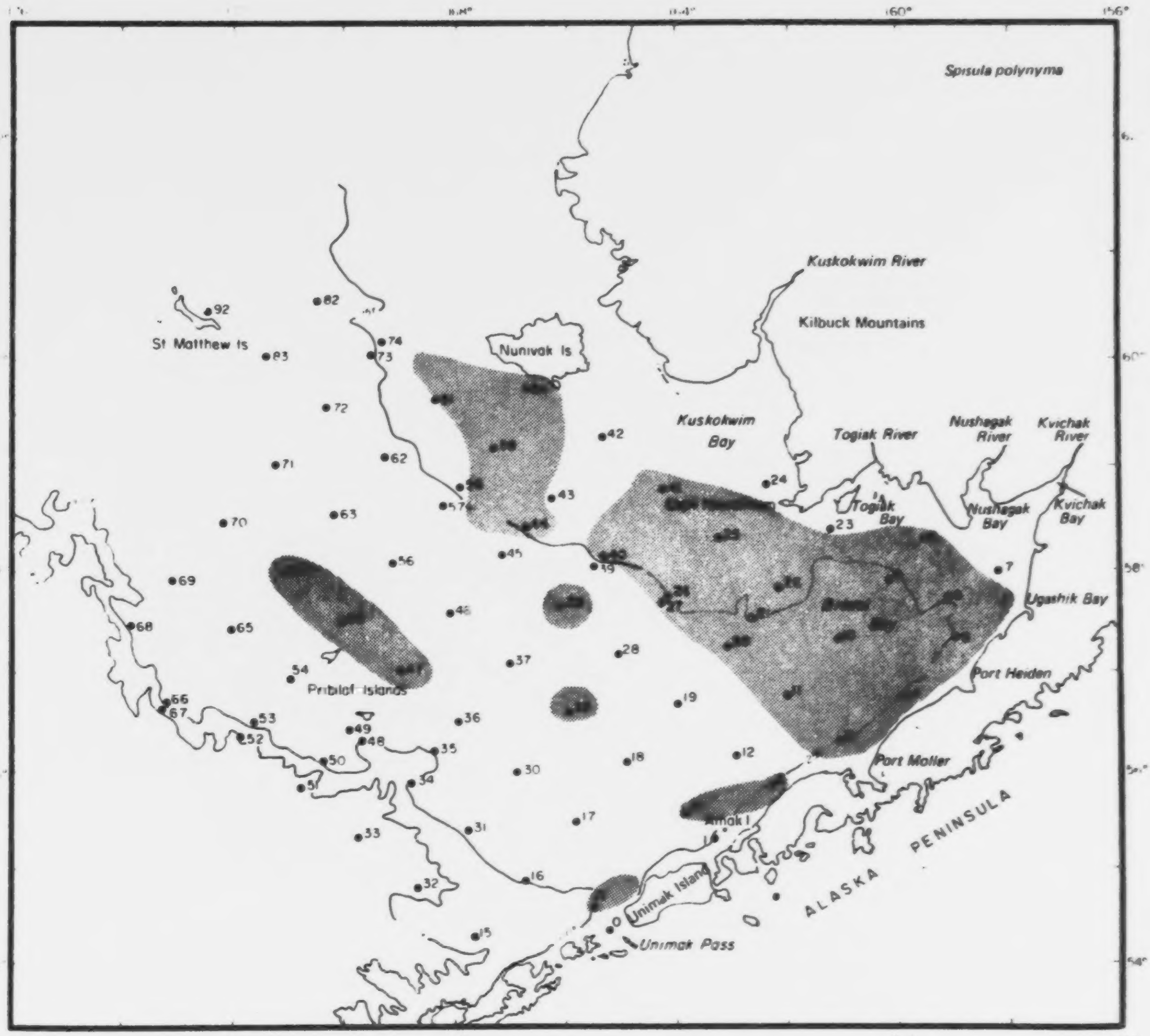

Tellina lutea
.8 – 0 φ
1 – 3 φ
3 – 4 φ
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 2.28. Distribution of *Tellina lutea* collected by pipe dredge, and phi values associated with the clam distribution.

BEST DOCUMENT AVAILABLE



Spisula polynyma
160°
156°
58°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
71
62
70
63
57
43
42
24
23
7
69
56
45
39
68
65
46
37
28
54
19
66
67
53
52
49
48
36
35
18
12
50
51
34
30
17
33
31
16
32
15
0

Figure 2.29. Distribution of *Spisula polynyma* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

Bivalve molluscs (mixed species) were most numerous at stations on the midportion of the southeastern shelf (Figs. 2.1, 2.7; Table 2.VI), as for example, Station 28 with 3374 indiv/m^2, Station 29: 834 indiv/m^2, Station 19: 1170 indiv./m^2, Station 935: 796 indiv/m^2, and Station 12: 482 indiv/m^2. Large numbers of clams were also found at Stations 63 and 64 (554 and 1380 indiv/m^2, respectively) on the outer shelf and Station 71: 774 indiv/m^2 and Station 83 (574) on the central shelf.

Twelve of the 33 species of bivalve molluscs collected in the southeastern Bering Sea were each found in at least 18% of the stations sampled by grab (Appendix 2.A): *Nucula tenuis* (77% of the stations sampled), *Axinopsida serricata* (56%), *Thyasira flexuosa* (39%), *Nuculana fossa* (36%), *Yoldia scissurata* (28%), *Tellina lutea* (28%), *Cyclocardia crebricostata* (25%), *Yoldia amygdalea* (23%), *Macoma calcarea* (23%), *Clinocardium ciliatum* (21%), *Spisula polynyma* (20%) and *Serripes groenlandicus* (18%).

Bivalve (mixed species) biomass was generally greatest at stations on the inshore portion of the southeastern shelf (Figs. 2.1, 2.2; Table 2.VII), as for example, Station 5 with 573.1 g/m^2, Station 9: 158.4 g/m^2, Station 22: 87.6 g/m^2, Station 41: 90.1 g/m^2, Station 60: 72.1 g/m^2 and Station 59: 98.6 g/m^2. Large biomass values were also noted on the midportion of the shelf at Station 28: 2193.3 g/m^2, Station 63: 89.0 g/m^2, Station 1: 69.7 g/m^2, Station 71: 65.3 g/m^2 and Station 64: 63.4 g/m^2.

VII. DISCUSSION

Although bivalve molluscs and other benthic species exhibit patchy distributions, it is often possible to predict their occurrence based on associated sediment particle size and sediment sorting (Sanders, 1958, 1960; Stoker, 1973, 1978; Shevtsov, 1964), and depth. The data presented in this section suggest that, in general, the distribution of the bivalves *Nucula tenuis, Nuculana fossa, Cyclocardia crebricostata, Clinocardium ciliatum, Macoma calcarea, Yoldia amygdalea, Spisula polynyma* and *Tellina lutea* are associated with specific sediment size, sorting ranges and depth.

Five species of clams--*Nucula tenuis, Nuculana fossa, Yoldia amygdalea, Tellina lutea* and *Macoma calcarea*--are representatives of a major trophic

TABLE 2.VI

TOTAL NUMBER OF CLAMS/M^2 BY STATION ON THE SOUTHEASTERN BERING SEA SHELF

Table based on data in Appendix A

Station	Total No./m^2	Station	No./m^2	Station	No./m^2
1	756	24	8	59	21
3	36	25	43	60	12
4	20	27	14	61	8
5	105	28	3374	62	26
6	6	29	834	63	554
7	6	30	278	64	1380
8	162	31	183	65	446
9	206	35	26	70	87
10	52	36	142	71	774
11	264	37	6	72	250
12	482	38	46	73	6
13	93	39	12	82	262
14	4	40	11	83	574
15	16	41	15	924	54
16	56	42	32	935	796
17	206	43	26	937	426
18	590	45	664	939	242
19	1770	47	232	941	42
20	52	49	182	942	91
22	15	55	186		
23	42	57	14		

TABLE 2.VII

BIOMASS (G/M^2) BY STATION ON THE SOUTHEASTERN BERING SEA SHELF

Table based on data in Appendix C

Station	g/m^2	Station	g/m^2	Station	g/m^2
1	140.96	24	45.61	59	98.55
3	9.24	25	41.14	60	72.12
4	.05	27	6.18	61	7.55
5	573.14	28	2193.26	62	11.61
6	23.63	29	67.37	63	89.01
7	61.86	30	3.50	64	63.34
8	8.71	31	2.20	65	9.76
9	158.35	35	.61	70	13.89
10	57.53	36	2.39	71	65.32
11	5.99	37	1.54	72	26.15
12	13.51	38	.57	73	.07
13	4.22	39	.43	82	18.07
14	.07	40	.75	83	50.08
15	.34	41	90.09	924	2.88
16	.29	42	1.93	935	11.18
17	1.35	43	.93	937	14.12
18	12.93	45	26.62	939	11.05
19	101.43	47	23.05	941	5.65
20	14.49	49	2.10	942	6.69
22	87.58	55	40.76		
23	74.03	57	.22		

group, detrital or deposit feeders, in the Bering Sea (Kusnetsov, 1964; Filatova and Barsonova, 1964). These clams are selective deposit feeders. They are typically found in areas of weak circulation and moderate sedimentation, usually in fine sand (2.25-3.0ϕ) and coarse silt (4.25-5.0ϕ) between 25-100 m. Although *N. tenuis*, *N. fossa*, and *Y. amygdalea* are primarily deposit feeders, *M. calcarea* and *T. lutea* may also function as suspension feeders (Filatova and Barsonova, 1964; Kuznetsov, 1964). The filter-feeding bivalves *Cyclocardia crebricostata*, *Clinocardium ciliatum* and *Spisula polynyma* also occur in these sediment regimes. The former two species are probably able to readily utilize resuspended detrital debris from several centimeters above the water-sediment interface in such areas (Hoskin *et al.*, 1976; Hoskin 1977; Mueller *et al.*, 1976).

The organic carbon of marine sediments is derived from (1) remote regions (allochthonous carbon: imported into the ecosystem), such as river systems, and (2) overlying water column productivity (autochthonous carbon: produced within an ecosystem). The quality and quantity of the organic carbon of the bottom are related to the distance and source of allochthonous material, carbon coupling activities in the overlying water column, suspended particle-size and settling rates, resuspension mechanisms, and the microbial composition and activity found within the bottom sediments. Organic carbon occurs in significant concentrations near the Togiak Bay and outer Bering shelf regions (Figs. 2.1, 2.7). In these regions, the organic carbon content of sediments is directly proportional to the clay content of the sediment (Sharma, 1972). It has been suggested that organic material is generally transported and deposited with fine silts or clay sized sediments. The latter processes may result from adsorption of organics on the clay-sized particles and/or by current systems which control distribution and deposition of materials carried in suspension (Sanders, 1958; Sharma, 1972; Hoskin, 1978; Driscoll and Brandon, 1973). The relatively greater silt and clay content and amount of organic matter on the outer Bering Sea shelf region and adjacent areas may partly explain the high numbers and biomass of bivalves at Stations 55, 63, 64, 65, 71, 72, and 83 northwest of the Pribilof Islands and south of St. Matthew Island.

There are many other factors, not considered in this section, that probably influence the distribution of pelecypods in the southeastern Bering Sea. Further data are needed to comprehend the importance of each factor. These factors include predation (Shubnikov and Lisovenko, 1961; Skalkin, 1960; Neiman, 1964; Feder *et al.*, 1978c), circulation intensity of the overlying waters (Takenouti and Ohtani, 1972), concentrations of suspended material in the overlying water (Sharma *et al.*, 1972; Sharma, 1972), organic content of the sediments (Driscoll and Brandon, 1973; Franz, 1976), bottom temperature (Neiman, 1960, 1964; Semenov, 1964), effectiveness of grazing in the overlying water column, i.e. efficiency of carbon coupling in the water column (Alexander and Cooney, 1979), and the microbial ecology of the sediment system of the shelf (Morita, Personal communication).

It has been suggested by Alexander and Cooney (1979) that an uncoupled carbon system may occur within the water column of the midportion of the southeastern Bering Sea shelf (Fig. 2.1). The zooplankton here is apparently unable to graze the phytoplankton as rapidly as it is produced nor is the zooplankton successfully able to graze the larger species of diatoms. Consequently, it is assumed that much of the carbon produced as phytoplankton reaches the bottom where it becomes available to suspension and deposit-feeding invertebrates. The presence of dense populations of bivalve molluscs on the midportions of the southeast Bering Sea shelf (Stations 11, 12, 18, 19, 28, 29, 30) may reflect the fallout of phytoplankton in an uncoupled system. Likewise, the trophic importance of the mid-shelf region to its resident deposit-feeding species, inclusive of clams (Section 1, Appendix 1.B), is indicated by the presence of commercial quantities of snow crab, king crab and yellowfin sole that feed on deposit-feeding polychaetes and bivalve molluscs there (Feder *et al.*, 1978c; Feder and Jewett, in press; Pereyra *et al.*, 1976).

VIII. CONCLUSIONS

Sediment phi values (ϕ) increased with distance from shore, depth, and decreased circulation. The lowest values occurred in shallow water in very coarse to fine sand ($<0-3.0\phi$) with very well to moderately well sorted ($<0.35-0.71\delta_I$) sediments; biomass was typically the highest here. The greatest numbers of clams occurred in deep water in fine sand to medium silt ($>3.0-6.0\phi$) with moderately to very poorly sorted ($>0.71-4.0\delta_I$) sediments combined with high organic carbon content; the biomass was lowest here. The depth distributions of the eight pelecypod species overlapped extensively. *Macoma calcarea* occurred at depths of 25-125 m with 97% between 50-100 m; *Cyclocardia crebricostata* at 25-75 m with 99% between 25-75 m; *Nucula tenuis* at <25-175 m with 92% between 50-150 m; *Nuculana fossa* at 50-175 m with 94% between 75-125 m; *Yoldia amygdalea* at 50->175 m with 92% between 75-100 m; *Tellina lutea* at <25-75 m with 78% between <25-50 m; *Spisula polynyma* at <25-100 m with 94% between 50-100 m; and *Clinocardium ciliatum* at 50-125 m with 97% between 50-75 m.

The sediment range for the bivalve species examined was as follows: *Macoma calcarea* in medium sand to coarse silt with 94% in coarse silt; *Cyclocardia crebricostata* in coarse sand to coarse silt with 76% in very fine sand; *Nucula tenuis* in fine sand to medium silt with 91% in very fine sand to coarse silt; *Nuculana fossa* in fine sand to medium silt with 84% in very fine sand to coarse silt; *Yoldia amygdalea* in fine sand to medium silt with 89% in very fine sand to coarse silt; *Tellina lutea* in very coarse sand to coarse silt with 70% in fine sand; *Spisula polynyma* in fine sand to coarse silt with 59% in fine sand to coarse silt. *Clinocardium ciliatum* in very fine sand to medium silt with 98% in very fine sand to coarse silt.

The sediment sorting for the eight bivalve species also overlapped extensively. *Macoma calcarea* occurred in moderately well to poorly sorted sediments with 98% within poorly sorted sediments; *Clinocardium ciliatum* with 100% within poorly sorted sediments; *Nucula tenuis* in very well to very poorly sorted with 75% within poorly sorted sediments; *Nuculana fossa* in moderately to very poorly sorted with 96% within poorly sorted sediments; *Yoldia amygdalea* in well to very poorly sorted with 89% within poorly sorted sediments; *Tellina lutea* in very well to very poorly sorted with 39% within well sorted and 44% at poorly sorted sediments; *Spisula polynyma* in very well to poorly sorted sediments with 32% within moderately well sorted and 59% at poorly sorted sediments; and *Cyclocardia crebricostata* in well to poorly sorted with 58% within moderately sorted sediments.

The availability of biological information for eight species of readily identifiable bivalve molluscs, in conjunction with general infaunal information in the southeastern Bering Sea, represents a substantial basis for development of an infaunal monitoring program there. The data presented in this section address important aspectcs of the biology of clams, i.e., distribution relative to depth and sediment parameters, size at age, growth, and mortality. Although most of the data on the eight species of clams are preliminary, the existing information should increase the reliability of future monitoring programs in the southeastern Bering Sea. Furthermore, information for the clams considered in this report is applicable to these other species in Alaskan waters, and can probably be used for maintaining areas other than the southeastern Bering Sea.

APPENDIX 2.A

SOUTHEASTERN BERING SEA GRAB DATA 1975
THE DENSITY (COUNTS/M^2) OF ALL CLAMS TAKEN BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA (Fig. 2.7)

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	1	3	4	5	6	7	8	9
A. BOREALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	0*	0	0	0	0*
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	44	0	0	0	0	0	0	3
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	258	0	10	15	4	0	0	10
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	10	0	0	0	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	2	0	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0*	0*	0	0	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	2	0	0	0	0	0	0	0
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	0	0*	0	0*	0	0	2	0
MACOMA LAMA	COUNTS/METER SQUARED	332	4	0	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NUCULA TENUIS	COUNTS/METER SQUARED	62	0*	0	0	0	0	10	3
NUCULANA FOSSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	0	8	0	0	0	0	0	0
SILIQUA ALTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	16	0*	0	0	0	2	181
TELLINA LUTEA	COUNTS/METER SQUARED	0	6	0	90	2	6	144	7
THRACIA SP.	COUNTS/METER SQUARED	4	0	0	0	0	0	0	1
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
Y. SCISSURATA	COUNTS/METER SQUARED	54	0	0	0	0	0	4	1*
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
YOLDIA MYALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0

	STATIONS	10	11	12	13	14	15	16	17
A. BOREALIS	COUNTS/METER SQUARED	0	0	2	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	2	0	0	0	0	0	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	0	2	0	8	2	12	32	56
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	0	0	0	3	0	0	0	2
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	24	70	0	0	0	0	0	0
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	0	0	0	0	6	34
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0*	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	2	10	0	0	0	0	0	0
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0*	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	8	0	10	2	0	0	0	0*
MACOMA LAMA	COUNTS/METER SQUARED	10	0	0	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	0	0	0	0	0	0	0	4
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0*	0*	0	0	0	0	0	0*
NUCULA TENUIS	COUNTS/METER SQUARED	8	150	458	52	2	2	4	38
NUCULANA FOSSA	COUNTS/METER SQUARED	0	0	0	0	0	0	10	6
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SILIQUA ALTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	6	0	0	0	0	0	0
TELLINA LUTEA	COUNTS/METER SQUARED	0*	0	0	0*	0	0	0	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	13	0	0	0	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	0	0	2	0	0	2	2	66
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0*
Y. SCISSURATA	COUNTS/METER SQUARED	0	12	8	15	0	0	0	0
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	0	2	2	0	0	0	2	0
YOLDIA MYALIS	COUNTS/METER SQUARED	0	10	0*	0	0	0	0	0

BEST DOCUMENT AVAILABLE

460

SOUTHEASTERN BERING SEA GPAB DATA 1975

	STATIONS	18	19	20	22	23	24	25	27
A. BOREALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	0	0	0*	0*	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	14	440	0	0	0	0	0	0
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	14	0*	0	0	0	0	0	0
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0*	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	0	0	42	0	16	8	0	14
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	6	0	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	0*	0*	0	3	0	0	0	0
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	2	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	4	0	0	0	0	0*	0	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0*	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	0*	0	0	1	0	0	0*	0*
MACOMA LAMA	COUNTS/METER SQUARED	0	0	0	0	0*	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYA PRIAPUS	COUNTS/METER SQUARED	0*	0	0	0	0	0*	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NUCULA TENUIS	COUNTS/METER SQUARED	224	566	2	0	0	0	0	0*
NUCULANA FOSSA	COUNTS/METER SQUARED	18	10	0	0	0	0	0	0
PANDORA GLACIALIS	COUNTS/METER SQUARED	0*	0	0	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0*	2	0	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	0*	6	0	0*	0	0	0	0
SILIGUA ALTA	COUNTS/METER SQUARED	0	0	0	2	2	0	0*	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	0	0	1	0*	0	26	0
TELLINA LUTEA	COUNTS/METER SQUARED	0	0	2	7	24	0	1	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	1	0	0	16	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	316	738	4	0	0	0	0	0*
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
Y. SCISSURATA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0*
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	0*	2	0	0	0	0	0	0
YOLDIA MYALIS	COUNTS/METER SQUARED	0	0	0	0*	0	0*	0	0

	STATIONS	28	29	30	31	35	36	37	38
A. BOREALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	28	52	6	107	0	44	0	2
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	3030*	22	0	0	2	4	0	2
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	0	0	0	1	0	0	0	0
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	2	0	0	8	2	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0	0	0	8	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	2	0*
LYONSIA NORVEGICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. CORRUGATUS	COUNTS/METER SQUARED	14	0	0	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	16	0	0	0	0	0	0	0*
MACOMA LAMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	10	0	0	0	0	0	0	2
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	4	0	0	0	0	0	0	0
NUCULA TENUIS	COUNTS/METER SQUARED	142	562	268	15	4	28	0	28
NUCULANA FOSSA	COUNTS/METER SQUARED	14	96	4	9	2	40	4	0
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	2	2	0	0	0	4	0	0
SILIGUA ALTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	2
TELLINA LUTEA	COUNTS/METER SQUARED	66	0	0	0	0	0	0	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	26	98	0	50	10	12	0	10
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
Y. SCISSURATA	COUNTS/METER SQUARED	18	0	0	0	0	0	0	0
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	4	0	0	1	0	0	0	0*
YOLDIA MYALIS	COUNTS/METER SQUARED	0*	0	0*	0	0	0	0	0

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	39	40	41	42	43	45	49	57
A. BOREALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	6	0	0	0	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	2	2	0	2	0	600	137	4
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	0	0	0	0	0	0	15	0
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	0*	0	0*	0	6	0	0	0
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	4	0	0*	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	0	2	0	0	0	0	0	0
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	0*	0	1	0	0	10	0	0
MACOMA LAMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	2	0	0	0	0*	0	0	0
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NUCULA TENUIS	COUNTS/METER SQUARED	0*	3	0	20	2	50	3	1
NUCULANA FOSSA	COUNTS/METER SQUARED	0	0	0	0	0	0	27	0
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	0	0	4	0	0	0	0	1
SILIQUA ALTA	COUNTS/METER SQUARED	0	0	3	0	0*	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	0*	4	0	0	0	0	0
TELLINA LUTEA	COUNTS/METER SQUARED	2	0	3	4	6	0	0	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	0	0*	0	0	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	0*	2	0	0	12	3	0	1
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
Y. SCISSURATA	COUNTS/METER SQUARED	2	2	0	0	0	1	0	7
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
YOLDIA MYALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0

	STATIONS	59	60	61	62	63	64	65	924
A. BOREALIS	COUNTS/METER SQUARED	0	1	0	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	0	0	0	2	0	0	46	44
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	0	0	0	0	0	6	4	0
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	0	7	0	0	0	0	0	0
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	1	0	0	0	0	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	3	0	0	0	0	0	2	0
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	0*	0	0	2	96	364	10	0
MACOMA LAMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NUCULA TENUIS	COUNTS/METER SQUARED	5	0	4	10	422	20	12	6
NUCULANA FOSSA	COUNTS/METER SQUARED	0	0	0	0	0	620	262	2
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	5	0	2	0	0	0	0	0
SILIQUA ALTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0*	1	0	0	0	256	0	0
TELLINA LUTEA	COUNTS/METER SQUARED	3	2	0	0	0	0	0	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	0	0	0	6	0	2	110	0
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
Y. SCISSURATA	COUNTS/METER SQUARED	5	0	2	6	0	0	0	0
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	0	0	0	0	36	112	0	0
YOLDIA MYALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	935	937	939	941	942	47	55	70
A. BOREALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	0	0	0	0*	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	234	54	16	8	3	6	0	7
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	0	0	0	0	0	34	6	0*
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0	0	0*	0*
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	0	0	0	0	0	0	80	0
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	0	0	0	2	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0	0	0	4	0	0*
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	0	0	0	0	0	2	0*	0*
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	0	0	0*	0
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	0	0	0	0	0	0	0*	0*
MACOMA LAMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0*	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0*
NUCULA TENUIS	COUNTS/METER SQUARED	560	368	212	34	83	2	16	30
NUCULANA FOSSA	COUNTS/METER SQUARED	0	0	0	0	0	156	2	20
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0	0*	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0*	0	0	0	0*	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	0	0	14	0	0	0*	4	0*
SILIGUA ALTA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	0	0	0	0	2	76	0
TELLINA LUTEA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	0	5	0	0	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	0	0	0	0	0	14	0	10
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0*
Y. SCISSURATA	COUNTS/METER SQUARED	2	0	0	0	0	10	2	0
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	0	4	0	0	0	0	0*	20
YOLDIA HYALIS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0

	STATIONS	71	72	73	82	83
A. BOREALIS	COUNTS/METER SQUARED	0	0	0	0	0
ASTARTE MONTAGUI	COUNTS/METER SQUARED	0	0	0	0	0
AXINOPSIDA SERRICATA	COUNTS/METER SQUARED	18	6	0	0	0
CLINOCARDIUM CILIATUM	COUNTS/METER SQUARED	0	0	0	0	0
CLINOCARDIUM FUCANUM	COUNTS/METER SQUARED	0	0	0	0	0
CYCLOCARDIA CREBRICOSTATA	COUNTS/METER SQUARED	0	0	0	0	0
DACRYDIUM VITREUM	COUNTS/METER SQUARED	0	0	0	0	0
DIPLODONTA ALEUTICA	COUNTS/METER SQUARED	0	0	0	0	0
HIATELLA ARCTICA	COUNTS/METER SQUARED	0	0	0	0	0
LIOCYMA FLUCTUOSA	COUNTS/METER SQUARED	0	0	0	0	0
LYONSIA NORVEGICA	COUNTS/METER SQUARED	0	0	0	0	0
M. CORRUGATUS	COUNTS/METER SQUARED	0	0	0	0	0
M. CRASSULA	COUNTS/METER SQUARED	0	0	0	0	2
M. MOESTA MOESTA	COUNTS/METER SQUARED	0	0	0	0	0
MACOMA CALCAREA	COUNTS/METER SQUARED	0	6	0	0	46
MACOMA LAMA	COUNTS/METER SQUARED	0	0	0	0	0
MUSCULUS NIGER	COUNTS/METER SQUARED	0	0	0	0	0
MYA PRIAPUS	COUNTS/METER SQUARED	0	0	0	0	0
MYSELLA PLANATA	COUNTS/METER SQUARED	0	0	0	0	0
NUCULA TENUIS	COUNTS/METER SQUARED	548	190	6	252	494
NUCULANA FOSSA	COUNTS/METER SQUARED	150	24	0	2	22
PANDORA GLACIALIS	COUNTS/METER SQUARED	0	0	0	0	0
PERIPLOMA ALASKANA	COUNTS/METER SQUARED	0	0	0	0	0
SERRIPES GROENLANDICUS	COUNTS/METER SQUARED	0	0	0	0	0
SILIGUA ALTA	COUNTS/METER SQUARED	0	0	0	0	0
SPISULA POLYNYMA	COUNTS/METER SQUARED	0	0	0	0	0
TELLINA LUTEA	COUNTS/METER SQUARED	0	0	0	0	0
THRACIA SP.	COUNTS/METER SQUARED	0	0	0	0	0
THYASIRA FLEXUOSA	COUNTS/METER SQUARED	0	4	0	0	8
Y. MONTEREYENSIS	COUNTS/METER SQUARED	0	0	0	0	0
Y. SCISSURATA	COUNTS/METER SQUARED	0	0	0	0	0
YOLDIA AMYGDALEA	COUNTS/METER SQUARED	58	20	0	8	2
YOLDIA HYALIS	COUNTS/METER SQUARED	0	0	0	0	0

APPENDIX 2.B

SOUTHEASTERN BERING SEA CLAMS COLLECTED BY PIPE DREDGE ON THE NOAA VESSEL *MILLER FREEMAN*, MAY 1976

(See Fig. 2.7 for Station Locations)

APPENDIX 2.B

SOUTHEASTERN BERING SEA CLAMS COLLECTED BY PIPE DREDGE ON THE NOAA VESSEL *MILLER FREEMAN*, MAY 1976*

Species	13	12	3'	4	5**	5	6	9	23	69A	24	41	25	22	10	11	19	18	17	16	30	55	86A
Astarte montagui	-	-	-	-	-	2	-	2	-	-	2	-	1	-	-	1	-	-	-	-	-	2	-
Astarte borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clinocardium ciliatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	11	-	-	-	2	-
C. fucanum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
Serripes groenlandicus	-	-	5	-	-	-	-	-	-	2	-	-	-	1	-	-	1	-	-	-	-	1	-
Cyclocardia crebricostata	-	-	60	2	15	1	40	3	11	-	49	6	-	-	29	8	-	-	-	-	-	384	-
Hiatella arctica	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mysella planata	-	-	-	-	-	-	-	-	-	3	-	-	-	-	6	1	-	23	-	-	-	9	2
Lyonsia norvegica	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	2	-	-	-	-	-
Spisula polynyma	-	-	8	2	-	-	-	17	2	-	-	-	-	1	-	-	-	-	-	-	-	34	-
Mya priapus	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	5	-	-	-	5	-
Dacrydium vitreum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
Musculus niger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Musculus corrugatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
Yoldia myalis	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	4	-	-
Y. amygdalea	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	4	7	-	1	-	12	3
Y. montereyensis	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	16	-	-	-	-
Y. scissurata	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	2	-
Nuculana fossa	-	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	2	15	12	12	14	-	3
Nucula tenuis	-	500	1	-	-	-	-	-	-	72	-	-	-	-	2	8	116	65	3	-	55	13	8
Pandora glacialis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Periploma alaskana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1
Siliqua alta	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Macoma calcarea	-	-	3	-	-	1	-	-	-	53	44	-	1	-	29	-	1	1	-	-	-	-	10
M. lama	-	-	6	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. moesta	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
M. crassula	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	1	-
Tellina lutea	-	1	1	7	32	59	11	1	26	-	-	4	7	18	-	-	-	-	-	-	-	-	-
Thracia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Thyasira flexuosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	100	-	5	-	-	-
Axinopsida serricata	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplodonta aleutica	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liocyma fluctuosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4

BEST DOCUMENT AVAILABLE

APPENDIX 2.B

CONTINUED

Species	64	69	86B	70	70A	46	56	37	47A	38-1	38-2	43	40	59	44	39	26	28	18A	27	2
										Station Number											
Astarte montagui	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Astarte borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clinocardium ciliatum	5	-	-	4	-	-	-	5	168	-	1	-	-	-	-	-	-	approx 7040	7	-	-
C. fucanum	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Serripes groenlandicus	-	-	-	1	4	1	-	-	3	-	-	-	-	1	-	-	-	4	1	-	-
Cyclocardia crebricostata	2	11	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	6	-
Hiatella arctica	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mysella planata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lyonsia norvegica	-	-	-	-	1	-	-	-	5	-	-	-	-	1	1	-	3	-	-	-	-
Spisula polynyma	-	-	-	-	-	-	-	-	2	-	-	-	1	1	8	-	-	-	-	-	-
Mya priapus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Dacrydium vitreum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Musculus niger	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	26	1	-	-
Musculus corrugatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yoldia myalis	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-
Y. amygdalea	27	-	5	18	79	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-
Y. montereyensis	-	-	-	13	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Y. scissurata	1	-	-	-	-	-	-	-	3	-	-	-	2	8	3	5	-	-	-	2	-
Nuculana fossa	127	-	13	115	20	-	-	-	1	-	-	-	-	-	-	-	-	56	21	-	-
Nucula tenuis	6	-	29	80	44	-	3	4	-	26	10	-	-	-	-	1	-	39	10	1	-
Pandora glacialis	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	1	-	-
Periploma alaskana	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Siliqua alta	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Macoma calcarea	247	1	20	320	241	15	6	7	-	6	1	-	-	10	6	6	-	198	1	2	-
M. lama	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. moesta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. crassula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tellina lutea	-	-	-	-	-	-	-	-	-	-	-	1	-	2	2	-	-	-	-	-	1
Thracia sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Thyasira flexuosa	-	-	1	-	-	1	-	-	-	-	-	1	-	-	-	2	-	-	2	1	-
Axinopsida serricata	-	6	200	9	31	-	-	1	-	11	-	-	-	-	-	-	-	-	200	-	-
Diplodonta aleutica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liocyma fluctuosa	-	3	-	-	-	12	2	-	-	-	2	-	-	-	-	3	-	-	-	-	-

* Numbers represent total number of individuals.
**Clam dredge.

BEST DOCUMENT AVAILABLE

APPENDIX 2.C

SOUTHEASTERN BERING SEA GRAB DATA 1975
THE BIOMASS (FORMALIN WET WEIGHT; GRAMS/M^2) OF ALL CLAMS TAKEN BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA
(Fig. 2.7)

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	1	3	4	5	6	7	8	9
A. BOREALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.350	0.	0.	0.	0.	0.	0.	0.004
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	68.728	0.	0.043	1.835	11.208	0.	0.	4.571
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.003	0.	0.	0.	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.004	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.012	0.	0.	0.	0.	0.	0.	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.032	0.
MACOMA LAMA	GM/METER SQUARED	0.018	7.216	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	1.012	0.	0.	0.	0.	0.	0.112	0.123
NUCULANA FOSSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.	1.956	0.	0.	0.	0.	0.	0.
SILIGUA ALTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.042	0.	0.	0.	0.	0.092	128.373
TELLINA LUTEA	GM/METER SQUARED	0.	0.016	0.	571.300	12.418	61.861	5.682	23.565
THRACIA SP.	GM/METER SQUARED	0.026	0.	0.	0.	0.	0.	0.	0.024
THYASIRA FLEXUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	71.812	0.	0.	0.	0.	0.	2.792	1.690
YOLDIA AMYGDALEA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

	STATIONS	10	11	12	13	14	15	16	17
A. BOREALIS	GM/METER SQUARED	0.	0.	0.062	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.540	0.	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.	0.006	0.	0.114	0.064	0.032	0.052	0.082
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.	0.	0.	0.532	0.	0.	0.	0.008
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	1.530	3.076	0.	0.	0.	0.	0.	0.
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.026	0.306
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.192	0.588	0.	0.	0.	0.	0.	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	33.694	0.	0.296	1.830	0.	0.	0.	0.
MACOMA LAMA	GM/METER SQUARED	21.988	0.	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.212
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	0.126	1.082	1.620	1.191	0.004	0.262	0.008	0.590
NUCULANA FOSSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.136	0.050
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SILIGUA ALTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.370	0.	0.	0.	0.	0.	0.
TELLINA LUTEA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.072	0.	0.	0.	0.
THYASIRA FLEXUOSA	GM/METER SQUARED	0.	0.	0.046	0.	0.	0.022	0.062	0.102
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	0.	0.182	11.404	0.483	0.	0.	0.	0.
YOLDIA AMYGDALEA	GM/METER SQUARED	0.	0.072	0.082	0.	0.	0.	0.002	0.
YOLDIA MYALIS	GM/METER SQUARED	0.	0.072	0.	0.	0.	0.	0.	0.

BEST DOCUMENT AVAILABLE

468

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	18	19	20	22	23	24	25	27
A. BOREALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.024	1.380	0.	0.	0.	0.	0.	0.
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.398	0.	0.	0.	0.	0.	0.	0.
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	0.	0.	14.318	0.	0.850	45.608	0.	6.182
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	3.614	0.	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.	0.	0.	0.071	0.	0.	0.	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.112	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.786	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	0.	0.	0.	8.945	0.	0.	0.	0.
MACOMA LAMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	8.270	27.530	0.014	0.	0.	0.	0.	0.
NUCULANA FOSSA	GM/METER SQUARED	2.942	0.172	0.	0.	0.	0.	0.	0.
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	2.312	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.	59.910	0.	0.	0.	0.	0.	0.
SILIGUA ALTA	GM/METER SQUARED	0.	0.	0.	0.856	2.878	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.	0.	0.132	0.	0.	0.060	0.
TELLINA LUTEA	GM/METER SQUARED	0.	0.	0.008	77.566	70.304	0.	41.064	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.007	0.	0.	0.016	0.
THYASIRA FLEXUOSA	GM/METER SQUARED	0.532	6.426	0.036	0.	0.	0.	0.	0.
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
YOLDIA AMYGDALEA	GM/METER SQUARED	0.	0.096	0.	0.	0.	0.	0.	0.
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

	STATIONS	28	29	30	31	35	36	37	38
A. BOREALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	4.208	0.106	0.006	0.131	0.	0.068	0.	0.006
CLINOCARDIUM CILIATUM	GM/METER SQUARED	2118.376	11.096	0.	0.	0.016	0.110	0.	0.016
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	0.	0.	0.	0.466	0.	0.	0.	0.
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.016	0.	0.	0.032	0.012	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.182	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	1.526	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. CORRUGATUS	GM/METER SQUARED	5.808	0.	0.	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	2.368	0.	0.	0.	0.	0.	0.	0.
MACOMA LAMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	3.248	0.	0.	0.	0.	0.	0.	0.016
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.018	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	24.588	23.178	3.460	0.132	0.020	0.392	0.	0.502
NUCULANA FOSSA	GM/METER SQUARED	5.670	32.500	0.034	1.242	0.330	1.606	0.014	0.
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	3.804	0.234	0.	0.	0.	0.008	0.	0.
SILIGUA ALTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.006
TELLINA LUTEA	GM/METER SQUARED	8.324	0.	0.	0.	0.	0.	0.	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
THYASIRA FLEXUOSA	GM/METER SQUARED	0.010	0.240	0.	0.226	0.210	0.014	0.	0.022
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	6.496	0.	0.	0.	0.	0.	0.	0.
YOLDIA AMYGDALEA	GM/METER SQUARED	2.344	0.	0.	0.005	0.	0.	0.	0.
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

SOUTHEASTERN BERING SEA GPAB DATA 1975

	STATIONS	39	40	41	42	43	45	49	57
A. BOREALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.156	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.002	0.003	0.	0.002	0.	0.721	0.344	0.004
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.160	0.
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	0.	0.	0.	0.	0.036	0.	0.	0.
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.400	0.	0.	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.	0.683	0.	0.	0.	0.	0.	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	0.	0.	0.029	0.	0.	15.446	0.	0.
MACOMA LAMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.004	0.	0.	0.	0.	0.	0.	0.
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	0.	0.008	0.	1.366	0.004	2.307	0.180	0.004
NUCULANA FOSSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	1.411	0.
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.	0.	0.006	0.	0.	0.	0.	0.004
SILIGUA ALTA	GM/METER SQUARED	0.	0.	3.117	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.	0.047	0.	0.	0.	0.	0.
TELLINA LUTEA	GM/METER SQUARED	0.010	0.	86.895	0.406	0.076	0.	0.	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
THYASIPA FLEXUOSA	GM/METER SQUARED	0.	0.005	0.	0.	0.816	0.183	0.	0.114
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	0.016	0.047	0.	0.	0.	7.964	0.	0.093
YOLDIA AMYGDALEA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

	STATIONS	59	60	61	62	63	64	65	924
A. BOREALIS	GM/METER SQUARED	0.	0.237	0.	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.	0.	0.	0.006	0.	0.	0.144	0.120
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.	0.	0.	0.	0.	2.292	0.616	0.
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	0.	17.238	0.	0.	0.	0.	0.	0.
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.001	0.	0.	0.	0.	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	5.928	0.	0.	0.	0.	0.	0.012	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	0.	0.	0.	0.058	13.120	10.098	0.924	0.
MACOMA LAMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	0.013	0.	0.044	0.062	35.310	0.212	0.504	1.138
NUCULANA FOSSA	GM/METER SQUARED	0.	0.	0.	0.	0.	40.478	7.112	1.622
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.718	0.	0.098	0.	0.	0.	0.	0.
SILIGUA ALTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.169	0.	0.	0.	2.954	0.	0.
TELLINA LUTEA	GM/METER SQUARED	79.665	54.477	0.	0.	0.	0.	0.	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
THYASIRA FLEXUOSA	GM/METER SQUARED	0.	0.	0.	0.028	0.	0.	0.446	0.
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	12.228	0.	7.408	11.454	0.	0.	0.	0.
YOLDIA AMYGDALEA	GM/METER SQUARED	0.	0.	0.	0.	40.580	7.304	0.	0.
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	935	937	939	941	942	47	55	70
A. BOREALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.218	0.094	0.010	0.008	0.010	0.002	0.	0.020
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.	0.	0.	0.	0.	10.584	1.102	0.
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	37.886	0.
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.	0.	0.	0.006	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.074	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.004	0.	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MACOMA LAMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	10.044	5.638	7.002	5.640	6.663	0.084	0.260	1.187
NUCULANA FOSSA	GM/METER SQUARED	0.	0.	0.	0.	0.	10.366	0.036	0.230
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.	0.	4.040	0.	0.	0.	0.162	0.
SILIQUA ALTA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.060	1.120	0.
TELLINA LUTEA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.	0.015	0.	0.	0.
THYASIRA FLEXUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.014	0.	0.030
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	0.920	0.	0.	0.	0.	1.860	0.192	0.
YOLDIA AMYGDALEA	GM/METER SQUARED	0.	8.386	0.	0.	0.	0.	0.	12.423
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

	STATIONS	71	72	73	82	83
A. BOREALIS	GM/METER SQUARED	0.	0.	0.	0.	0.
ASTARTE MONTAGUI	GM/METER SQUARED	0.	0.	0.	0.	0.
AXINOPSIDA SERRICATA	GM/METER SQUARED	0.048	0.022	0.	0.	0.
CLINOCARDIUM CILIATUM	GM/METER SQUARED	0.	0.	0.	0.	0.
CLINOCARDIUM FUCANUM	GM/METER SQUARED	0.	0.	0.	0.	0.
CYCLOCARDIA CREBRICOSTATA	GM/METER SQUARED	0.	0.	0.	0.	0.
DACRYDIUM VITREUM	GM/METER SQUARED	0.	0.	0.	0.	0.
DIPLODONTA ALEUTICA	GM/METER SQUARED	0.	0.	0.	0.	0.
HIATELLA ARCTICA	GM/METER SQUARED	0.	0.	0.	0.	0.
LIOCYMA FLUCTUOSA	GM/METER SQUARED	0.	0.	0.	0.	0.
LYONSIA NORVEGICA	GM/METER SQUARED	0.	0.	0.	0.	0.
M. CORRUGATUS	GM/METER SQUARED	0.	0.	0.	0.	0.
M. CRASSULA	GM/METER SQUARED	0.	0.	0.	0.	4.458
M. MOESTA MOESTA	GM/METER SQUARED	0.	0.	0.	0.	0.
MACOMA CALCAREA	GM/METER SQUARED	0.	6.628	0.	0.	7.160
MACOMA LAMA	GM/METER SQUARED	0.	0.	0.	0.	0.
MUSCULUS NIGER	GM/METER SQUARED	0.	0.	0.	0.	0.
MYA PRIAPUS	GM/METER SQUARED	0.	0.	0.	0.	0.
MYSELLA PLANATA	GM/METER SQUARED	0.	0.	0.	0.	0.
NUCULA TENUIS	GM/METER SQUARED	39.766	5.924	0.070	8.934	29.342
NUCULANA FOSSA	GM/METER SQUARED	12.880	0.710	0.	0.082	1.970
PANDORA GLACIALIS	GM/METER SQUARED	0.	0.	0.	0.	0.
PERIPLOMA ALASKANA	GM/METER SQUARED	0.	0.	0.	0.	0.
SERRIPES GROENLANDICUS	GM/METER SQUARED	0.	0.	0.	0.	0.
SILIQUA ALTA	GM/METER SQUARED	0.	0.	0.	0.	0.
SPISULA POLYNYMA	GM/METER SQUARED	0.	0.	0.	0.	0.
TELLINA LUTEA	GM/METER SQUARED	0.	0.	0.	0.	0.
THRACIA SP.	GM/METER SQUARED	0.	0.	0.	0.	0.
THYASIRA FLEXUOSA	GM/METER SQUARED	0.	0.032	0.	0.	0.148
Y. MONTEREYENSIS	GM/METER SQUARED	0.	0.	0.	0.	0.
Y. SCISSURATA	GM/METER SQUARED	0.	0.	0.	0.	0.
YOLDIA AMYGDALEA	GM/METER SQUARED	12.628	12.838	0.	9.056	6.998
YOLDIA MYALIS	GM/METER SQUARED	0.	0.	0.	0.	0.

APPENDIX 2.D

THREE PARAMETERS AT WHICH THE MAJOR CONCENTRATIONS OF EIGHT SPECIES OF CLAMS, TAKEN BY VAN VEEN GRAB, OCCUR IN THE SOUTHEASTERN BERING SEA

APPENDIX 2.D

SEDIMENT PARAMETERS AT WHICH THE MAJOR CONCENTRATIONS OF EIGHT SPECIES OF CLAMS, TAKEN BY VAN VEEN GRAB, OCCUR IN THE SOUTHEASTERN BERING SEA

Species	Sediment Size	Sediment Sorting	% Mud (range)	Depth	Text Figs.	Text Tables
Nucula tenuis	very fine sand to medium silt (91%)*	poorly sorted (75%)	0-70	50-100 m (92%)	2.8 -2.10	2.I-2.V
Nuculana fossa	very fine sand to medium silt (84%)	poorly sorted (96%)	0-60	75-150 m (94%)	2.11-2.13	2.I-2.V
Yoldia amygdalea	very fine sand to medium silt (89%)	poorly sorted (89%)	0-50	75-100 m (92%)	2.23-2.25	2.I-2.V
Cyclocardia crebricostata	fine to very fine sand (76%)	moderately sorted (58%)	0-20	25- 75 m (99%)	2.14-2.16	2.I-2.V
Clinocardium ciliatum	very fine sand to coarse silt (98%)	poorly sorted (100%)	0-70	50- 75 m (97%)	2.20-2.22	2.I-2.V
*Spisula polynyma***	fine sand to coarse silt (59%)	moderately well to poorly sorted (59%)	0-50	50-100 m (94%)	2.29	2.I-2.V
*Tellina lutea***	fine sand (70%)	well to poorly sorted (83%)	0-40	<25- 50 m (78%)	2.26-2.28	2.I.2.V
Macoma calcarea	medium silt (94%)	poorly sorted (98%)	0-50	50-100 m (97%)	2.17-2.19	2.I-2.V

---

* The percentages in parentheses throughout the table refer to the major concentration of the clam species at a given parameter.

***Tellina lutea* and *Spisula polynyma* are large clams that are not collected quantitatively for all sizes. Distributions for only the small, young individuals of the two clam species are represented for the three parameters.

SECTION 3

THE DISTRIBUTION OF COMMON INFAUNA, OTHER THAN CLAMS, AND SESSILE AND SLOW-MOVING EPIFAUNA IN THE SOUTHEASTERN BERING SEA

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OIL AND GAS DEVELOPMENT

The objectives of this study for the southeastern Bering Sea were to (1) examine the composition and distribution of 11 infaunal species (other than clams; also see Section 2) and slow-moving epifaunal species and one fish, as collected by a series of sampling devices-pipe dredge, van Veen grab, clam dredge (Section 4) and otter trawl, and (2) relate the distribution of selected species to depth and several sediment parameters.

The lowest densities of the 11 invertebrate species occurred in the midportion of the southeastern Bering Sea shelf at intermediate depths in very coarse sand to fine sand (<0-3.0ϕ) with moderately to poorly sorted sediments (>.71-2.0δ_I); the biomass was highest in this region. The greatest densities occurred in the outer portion of the shelf in deep water in fine sand to medium silt (>3.0-6.0ϕ) with moderately to very poorly sorted sediments (>.71-4.0δ_I) and high sediment organic carbon content; the biomass was lowest in this region.

The distributions of the 11 invertebrate species overlapped extensively. *Solariella obscura* occurred at depths of 25-175 m with 82% between <25-75 m; *S. varicosa* occurred at depths of 25-175 m with 79% between 50-100 m; *Margarites olivaceus* occurred at depths of 25-100 m with 66% between 25-50 m; *Natica clausa* occurred at depths of 25-175 m with 56% between 100-175 m; *Polinices pallida* occurred in depths of <25-100 m with 62% between 50-75 m; *Cylichna alba* occurred in depths of <25->175 m with 72% at 25-100 m; *Echinarachnius parma* occurred in depths of <25-100 m with 99% at <25-75 m; *Diamphiodia craterodmeta* occurred at depths of 25-125 m with 79% between 50-100 m; *Ophiura sarsi* occurred in depths of 50-125 m with 83% between 50-100 m; *Cucumaria calcigera* occurred at depths of 25-100 m with 98% between 50-75 m; *Boltenia ovifera* occurred at depths of 50-75 m with 100% between 50-75 m.

The sediment range for the invertebrates species examined was as follows: *Solariella obscura* in very coarse sand to medium silt with 59% in medium to fine sand; *S. varicosa* in fine sand to medium silt with 62% in fine to very fine sand; *Margarites olivaceus* in coarse sand to medium silt with 80% in medium to fine sand; *Natica clausa* in very coarse sand to coarse silt with 63% in medium sand to coarse silt; *Polinices pallida* in medium sand to coarse silt with 72% in fine sand to coarse silt; *Cylichna alba* in coarse sand to medium silt with 98% in medium sand to medium silt; *Echinarachnius parma* in very coarse sand to coarse silt with 69% in medium to fine sand; *Diamphiodia craterodmeta* in fine sand to medium silt with 86% in fine sand to coarse silt; *Ophiura sarsi* fine sand to coarse silt with 82% in fine to very fine sand; *Cucumaria calcigera* in fine sand to coarse silt with 98% in very fine sand to coarse silt; *Boltenia ovifera* in coarse to medium sand with 100% in coarse to medium sand.

The sediment sorting for the invertebrate species also overlapped extensively. *Solariella obscura* in very well to very poorly sorted sediments with 52% within very well to moderately well sorted sediments; *S. varicosa* in well to very poorly sorted with 67% within poorly sorted sediments; *Margarites olivaceus* in very well to very poorly sorted with 79% within poorly sorted sediments; *Natica clausa* in very well to very poorly sorted with 56% within poorly to very poorly sorted sediments; *Polinices pallida* in very well to poorly sorted with 52% within very well to moderately sorted sediments; *Cylichna alba* in very well to very poorly sorted with 62% within moderately to poorly sorted sediments; *Echinarachnius parma* in very well to poorly sorted with 72% within well to moderately well sorted sediments; *Diamphiodia craterodmeta* in very well to poorly sorted with 88% within poorly sorted sediments; *Ophiura sarsi* in well to poorly sorted with 97% within poorly sorted sediments; *Cucumaria calcigera* in poorly to very poorly sorted with 99% in poorly sorted sediments; *Boltenia ovifera* in poorly sorted with 100% within poorly sorted sediments.

See Section 1 for comments on Implications with Respect to Oil and Gas Development.

II. INTRODUCTION

General Nature and Scope of Study

See general comments under this heading in Section 1.

It is the intent of this section to (1) examine the distribution of selected non-clam infaunal species and slow-moving epifauna, two species of sessile epifauna, and one species of fish as collected by a variety of gear, and (2) relate the distribution of dominant species treated in (1) to depth and selected sediment parameters.

Relevance to Problems of Petroleum Development

See general comments under this heading in Section 1.

III. CURRENT STATE OF KNOWLEDGE

See comments under this heading in Section 1. Also, see Appendices 1.A and 1.B for a list of infaunal species collected by van Veen grab in the southeastern Bering Sea study area, comments on species diversity, a numerical analysis of the distribution of all of the infaunal species collected, and comments on infaunal feeding types.

IV. STUDY AREA

See comments under this heading in Sections 1 and 2. See Feder *et al.*, 1978c and Feder and Jewett, in press, for area trawled, and Section 4 for area collected by hydraulic clam dredge.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

See Methods from the preceeding sections for details of collection procedures.

The 11 common species treated in detail in this section are the snails - *Solariella obscura, S. varicosa, Margarites olivaceus, Natica clausa, Polinices pallida*; the opisthobranch gastropod - *Cylichna alba*; the heart urchin - *Echinarachnius parma*; the brittle stars - *Diamphiodia craterodmeta, Ophiura sarsi*; the sea cucumber - *Cucumaria calcigera*; the tunicate - *Boltenia ovifera.*

Since only minor differences in species composition and distribution were noted in the trawl collections (Feder *et al.*, 1978c; Feder and Jewett, in press) and clam dredge material (Section 4). All calculations presented below are based on pipe dredge and van Veen grab samples only.

VI. RESULTS

Thirteen phyla were taken by using a combination of pipe dredge and van Veen grab as sampling tools. Use of the pipe dredge resulted in the collection of animals from 11 phyla, 55 families, and 142 species of infaunal invertebrates (Table 3.I). Sampling with the van Veen grab resulted in the collection of 11 phyla and 464 infaunal species (Tables 3.I, 3.II; Appendix 1.B). Two additional phyla were added by use of the grab, Priapulida and Brachiopoda; two phyla collected by pipe dredge were not taken by the grab, Protozoa and Porifera.

The small snail, *Solariella obscura*, was well distributed over the southeastern shelf, but tended to occur mainly in the mid-regions of this portion of the shelf. It extended into the northeastern portion of the central shelf. The greatest abundance of this species occurred at Stations 8, 22, 47, 57 and 62 (Fig. 3.1; Appendices 3.A and 3.B). The greatest biomass occurred at Stations 8, 9, 19, 22, 27, 57, and 61 (Appendix 3.C). The snail was present at 54% of the stations sampled by van Veen grab (Appendix 3.A). *Solariella obscura* was associated with sediment types ranging from medium sand to medium silt (<1.8-5.2ϕ; Figs. 2.2-2.6; Fig. 3.1; Tables 3.II-3.V). Major Component of Collection: Fifty-nine percent (59%) of *S. obscura* occurred in medium to fine sand (2.0-3.0ϕ), with 52% of the gastropods at sediment sorting values from <.35-.71. Eighty-two percent (82%) of *S. obscura* occurred from <25-75 m (Appendix 3.D). Minor Component of Collection: Two percent (2%) of the gastropods occurred in coarse to medium sand (0.0-2.0ϕ), 28% in fine to very fine sand (3.0-4.0ϕ) and 31% in coarse to medium silt (4.24-5.2ϕ; Table 3.III), with 2% of the species at sediment sorting values of >.71-1.0, 41% at >1.0-2.0 and 5% at >2.0-4.0. Eighteen percent (18%) of *S. obscura* occurred at depths of 50-175 m (medium silt).

Solariella varicosa also occurred on the southeastern shelf but its distribution was more restricted with two disjunct bands of distributions occurring north and south, primarily on the mid-portion of the shelf. The greatest abundance of this species occurred at Stations 36, 47 and 935 (Fig. 3.1; Appendices 3.A, 3.B). The greatest biomass occurred at Stations 18, 36, 47 and 935 (Appendix 3.C). This snail was present at 32% of the stations sampled by van Veen grab (Appendix 3.A). *Solariella*

TABLE 3.I

SPECIES COLLECTED BY PIPE DREDGE AT 44 STATIONS IN THE SOUTHEAST BERING SEA

Species	Station occurrences	% Occurrence of all stations
PROTOZOA		
Lagenidae		
Robulus spp.	1	2.2
Dentalina spp.	1	2.2
Elphidiidae		
Elphidium spp.	15	34.0
PORIFERA		
unidentified species	1	2.2
CNIDARIA		
Hydrozoa	8	18.1
Anthozoa		
Actiniidae	1	2.2
unidentified species		
ANNELIDA		
Polychaeta	27	61.3
Polynoidae	3	6.8
Nephtyidae		
Nephtys spp.	33	75.0
Onuphidae	3	6.8
Opheliidae	13	29.5
Ophelia limacina	2	4.5
Sternaspidae		
Sternaspis scutata	9	20.4
Pectinariidae		
Pectinaria belgica	17	38.6
Sabellidae	6	13.6
Hirudinea	7	15.9
MOLLUSCA		
Aplacophora	2	4.5
Pelecypoda	1	2.2
Nuculidae		
Nucula tenuis	23	52.2
Nuculanidae		
Nuculana fossa	14	31.8
Yoldia amygdalea	12	27.2
Yoldia myalis	7	15.9
Yoldia scissurata	10	22.7
Yoldia montereyensis	4	9.0
Mytilidae		
Musculus corrugatus	1	2.2
Musculus marmoratus	3	6.8
Dacrydium pacificum	1	2.2

TABLE 3.I

CONTINUED

Species	Station occurrences	% Occurrence of all stations
Astartidae		
Astarte borealis	1	2.2
Astarte montegui	6	13.6
Carditidae		
Cyclocardia crebricostata	16	36.3
Thyasiridae		
Axinopsida serricata	11	25.0
Thyasira flexuosa	6	13.6
Ungulinidae		
Diplodonta aleutica	2	4.5
Montacutidae		
Mysella planata	7	15.9
Cardiidae		
Clinocardium spp.	1	2.2
Clinocardium ciliatum	10	22.7
Clinocardium fucanum	2	4.5
Serripes groenlandicus	12	27.2
Veneridae		
Liocyma fluctuosa	6	13.6
Mactridae		
Spisula polynyma	10	22.7
Tellinidae		
Macoma spp.	1	2.2
Macoma calcarea	25	56.8
Macoma moesta moesta	2	4.5
Macoma crassula	2	4.5
Macoma lama	2	4.5
Tellina lutea alternidentata	15	34.0
Solenidae		
Siliqua alta	3	6.8
Myidae		
Mya japonica	1	2.2
Hiatella arctica	3	6.8
Pandoridae		
Pandora glacialis	2	4.5
Lyonsiidae		
Lyonsia norvegica	8	18.1
Periplomatidae		
Periploma alaskana	4	9.0
Thracia		
Thracia spp.	2	4.5
Gastropoda	2	4.5
Trochidae		
Margarites olivaceus	7	15.9
Margarites pupillus	1	2.2
Solariella obscura	18	40.9
Solariella varicosa	7	15.9

TABLE 3.I

CONTINUED

Species	Station occurrences	% Occurrence of all stations
Turritellidae		
Tachyrynchus erosus	3	6.8
Epitoniidae		
Epitonium groenlandicum	1	2.2
Trichotropididae		
Trichotropis borealis	1	2.2
Trichotropis kroyeri	1	2.2
Naticidae		
Natica clausa	8	18.1
Polinices pallida	21	47.7
Velutinidae		
Velutina spp.	3	6.8
Muricidae		
Trophonopsis dalli	1	2.2
Buccinidae		
Buccinum spp.	3	6.8
Buccinum polare	3	6.8
Neptunidae		
Colus spp.	2	4.5
Colus spitzbergensis	1	2.2
Colus hypolispus	2	4.5
Colus halli	2	4.5
Liomesus spp.	1	2.2
Liomesus ooides	1	2.2
Neptunea spp.	2	4.5
Neptunea lyrata	6	13.6
Neptunea ventricosa	2	4.5
Neptunea communis	5	11.3
Neptunea heros	1	2.2
Plicifusus spp.	3	6.8
Plicifusus virens	1	2.2
Volutopsius spp.	1	2.2
Cancellaridae		
Admete spp.	2	4.5
Admete couthouyi	4	9.0
Admete regina	5	11.3
Turridae	1	2.2
Oenopota spp.	8	18.1
Oenopota turricula	1	2.2
Oenopota harpa	2	4.5
Oenopota decussata	1	2.2
Propebela	15	34.0
Lora reticulata	1	2.2
Pyramidellidae		
Odostomia aleutica	3	6.8

TABLE 3.I

CONTINUED

Species	Station occurrences	% Occurrence of all stations
Scaphandridae		
Cylichna alba	24	54.5
Dentaliidae		
Dentalium spp.	3	6.8
ARTHROPODA		
Crustacea		
Balanidae		
Balanus spp.	3	6.8
Balanus balanus	2	4.5
Balanus hesperius	10	22.7
Mysidacea	4	9.0
Cumacea	13	29.5
Isopoda		
Idoteidae		
Synidotea bicuspida	1	2.2
Amphipoda		
Gammaridae		
Melita spp.	3	6.8
Melita dentata	2	4.5
Lysiannassidae		
Anonyx spp.	1	2.2
Caprellidae	1	2.2
Pandalidae		
Pandalus goniurus	1	2.2
Crangonidae		
Crangon dalli	11	25.0
Sclerocrangon boreas	1	2.2
Paguridae		
Pagurus spp.	1	2.2
Pagurus ochotensis	3	6.8
Pagurus capillatus	2	4.5
Pagurus trigonocheirus	7	15.9
Elassochirus tenuimanus	1	2.2
Majiidae		
Oregonia gracilis	3	6.8
Hyas coarctatus alutaceus	2	4.5
Chionoecetes bairdi	1	2.2
Atelecyclidae		
Telmessus cheiragonus	2	4.5
Pinnotheridae		
Pinnixa occidentalis	1	2.2
SIPUNCULA	5	11.3

TABLE 3.I

CONTINUED

Species	Station occurrences	% Occurrence of all stations
ECHIUROIDEA		
Echiurida		
Echiuridae		
Echiurus echiurus alaskanus	1	2.2
ECTOPROCTA	2	4.5
ECHINODERMATA		
Asteroidea		
Porcellgnasteridae		
Ctenodiscus crispatus	1	2.2
Solasteridae		
Lophaster furcilliger	2	4.5
Asteridae		
Asterias amurensis	5	11.3
Evasterias echinosoma	1	2.2
Leptasterias polaris	1	2.2
Echinoidae		
Echinarachniidae	1	2.2
Echinarachnius parma	13	
Ophiuridea		
Amphiuridae		
Diamphiodia craterodmeta	15	34.0
Ophiactidae		
Ophiopholis aculeata	1	2.2
Ophiuridae		
Ophiopenia disacantha	2	4.5
Ophiura spp.	1	2.2
Ophiura sarsi	10	22.7
Holothuroidea		
Synatpiidae	1	2.2
Cucumariidae		
Cucumaria spp.	1	2.2
Cucumaria calcigera	5	11.3
CHORDATA		
Subphylum Urochordata	4	9.0
Styelidae	1	2.2
Pyuridae	1	2.2
Boltenia ovifera	4	9.0
Subphylum Vertebrata		
Ammodytidae		
Ammodytes hexapterus	1	2.2

TABLE 3.II

THE INVERTEBRATE PHYLA AND THE NUMBER AND PERCENTAGE OF EACH PHYLUM COLLECTED BY PIPE DREDGE AND VAN VEEN GRAB IN THE BERING SEA

Phylum	Number of Species		% of Species	
	Pipe dredge	Grab	Pipe dredge	Grab
Porifera	1	-	7.0	-
Cnidaria	2	2	14.0	0.4
Annelida	10	194	7.0	41.8
Mollusca	76	117	53.5	25.2
Arthropoda (Crustacea)	30	119	21.1	25.7
Sipuncula	1	4	0.7	0.8
Priapulida	-	1	-	0.2
Echiuroidea	1	1	0.7	0.2
Ectoprocta	-	4	-	0.8
Brachiopoda	-	1	-	0.2
Echinodermata	15	17	10.6	3.7
Chordata (Urochordata)	4	4	2.8	0.8
Chordata (Teleostei:fishes)	1	-	0.7	-
Total	142	464	100.0%	100.0%

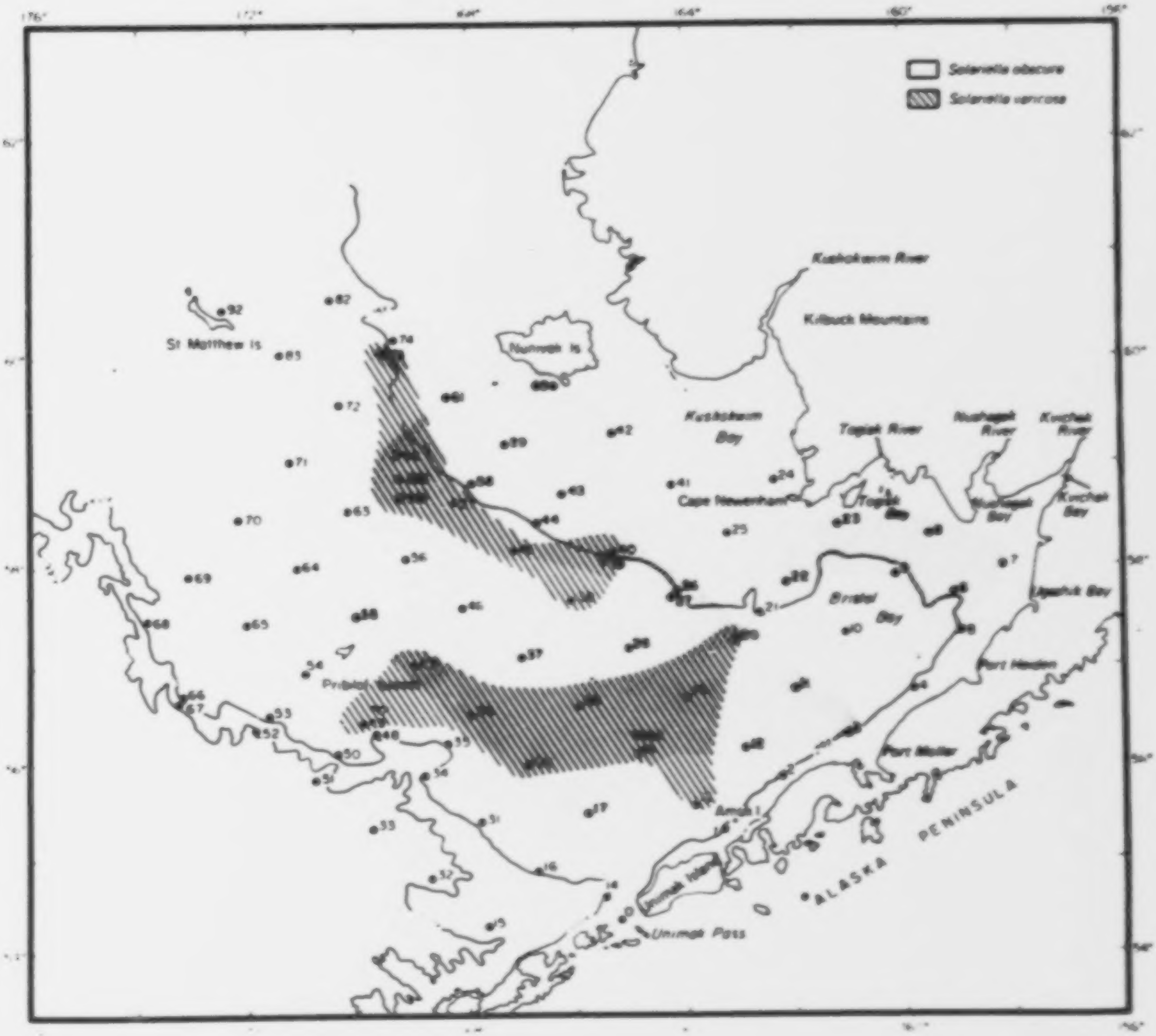

176°
172°
168°
164°
160°
156°
□ Solariella obscura
▨ Solariella varicosa
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Cape Newenham
Togiak River
Togiak Bay
Nushagak River
Nushagak Bay
Kvichak River
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
85
74
72
71
70
69
68
66
67
65
64
63
61
60
58
56
55
54
53
52
51
50
49
48
47
46
44
43
42
41
40
38
37
36
35
34
33
32
31
29
28
25
24
23
22
21
16
14
10
7
5

Figure 3.1. Distribution of *Solariella obscura* and *Solariella varicosa* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

varicosa was associated with sediment types ranging from medium sand to medium silt (2.0-5.7ϕ; Figs. 2.2-2.6, 3.1; Tables 3.II-3.V). Major Component of Collection: Sixty-two percent (62%) of *S. varicosa* occurred in fine sand to coarse silt (3.0-4.9ϕ) with 67% of the gastropods at sediment sorting values of >1.0-2.0. Sixty-nine percent (69%) of *S. varicosa* occurred from 50-100 m (Appendix 3.D). Minor Component of Collection: Three percent (3%) of these gastropods occurred in medium to fine sand (2.0-3.0ϕ) and 35% in coarse to medium silt (4.9-5.7ϕ; Table 3.III), with 4% of the species at sediment sorting values of .35-.5, 4% at >.71-1.0 and 25% at >2.0-4.0. Five percent (5%) of *S. varicosa* occurred at depths of 25-50 m (medium to fine sand) and 26% at 100-175 m (medium silt).

The snail, *Margarites olivaceus*, was primarily located within Bristol Bay with a few scattered locations in Kuskokwim Bay, Station 18 on the southwestern portion of the shelf, and at one station north of the Pribilof Islands. The greatest abundance of this species occurred at Stations 5, 11, 19 (Fig. 3.2; Appendices 3.A, 3.B). The greatest biomass occurred at Stations 5 and 19 (Appendix 3.C). The snail was present at 11% of the stations sampled by van Veen grab (Appendix 3.A). The small snail, *Margarites olivaceus*, was associated with sediment types ranging from coarse sand to medium silt (1.0-5.7ϕ; Figs. 2.1-2.6; Fig. 3.2; Tables 3.II-3.V). Major Component of Collection: Eighty percent (80%) of *M. olivaceus* occurred in medium to fine sand (2.0-3.0ϕ), with 79% of the gastropods at sediment sorting values of >1.0-2.0. Sixty-six percent (66%) of *M. olivaceus* occurred from 25-75 m (Appendix 3.D). Minor Component of Collection: Fifteen percent (15%) of these gastropods occurred in fine to very fine sand (3.0-4.0ϕ) and 5% at medium silt (50-5.7ϕ; Table 3.III), with 1% of the species at sediment sorting values of <.35, 2% at >.5-.71, 14% at >.71-1.0 and 4% at >2.0-4.0. Thirty-four percent (34%) of *M. olivaceus* occurred at depths of 75-100 m (medium silt).

The distribution of the predaceous snail, *Natica clausa*, was very restricted, but was mainly found on the southeastern shelf (Fig. 3.3). The greatest abundance of this species occurred at Stations 14, 22, 27 and 65; Appendices 3.A, 3.B). The greatest biomass occurred at Stations 14, 22 and 27 (Appendix 3.C). The snail was present at 7% of the stations

TABLE 3.III

PERCENT OF SELECTED BENTHIC SPECIES COLLECTED AT EACH PHI VALUE USING A VAN VEEN GRAB IN THE SOUTHEAST BERING SEA

(Based on counts/m^2)

	Phi Values						
Species	**-.8-0**	**<0-1**	**<1-2**	**<2-3**	**<3-4**	**<4-5**	**<5-6**
Solariella obscura		1	1	59	28	10	1
S. varicosa				3	62	27	8
Margarites olivaceus				80	15		5
Natica clausa		37		25	19	19	
Polinices pallida				28	37	35	
Cylichna alba			2	33	18	25	22
Echinarachnius parma		8	10	69	2	11	
Diamphiodia craterodmeta					45	41	14
Ophiura sarsi				2	82	16	
Cucumaria calcigera					2	98	
Boltenia ovifera			100				

TABLE 3.IV

PERCENT OF SELECTED BENTHIC SPECIES BY SEDIMENT SORTING VALUES BASED ON SOUTHEASTERN BERING SEA GRAB DATA 1975

(Based on counts/m^2)

	Sorting Values						
Species	**<.35**	**.35-.5**	**>.5-.71**	**>.71-1**	**>1-2**	**>2-4**	**>4-10**
Solariella obscura	17	25	10	2	41	5	0
Solariella varicosa	0	4	0	4	67	25	0
Margarites olivaceus	1	0	2	14	79	3	0
Natica clausa	24	0	19	0	19	37	0
Polinices pallida	10	24	18	8	32	8	0
Cylichna alba	18	3	9	13	49	8	0
Echinarachnius parma	5	37	35	0	23	0	0
Diamphiodia craterodmeta	0	0	0	1	88	11	0
Ophiura sarsi	0	1	1	0	97	1	0
Cucumaria calcigera	0	0	0	0	99	1	0
Boltenia ovifera	0	0	0	0	100	0	0

TABLE 3.V

PERCENT OF SELECTED BENTHIC SPECIES BY DEPTH BASED ON SOUTHEASTERN BERING SEA GRAB DATA 1975

(Based on counts/m^2)

	Depths of Occurrence in Percent							
Species	0-25	25-50	50-75	50-100	100-125	125-150	150-175	>175
Solariella obscura	25	24	33	13	3	1	1	0
Solariella varicosa	0	5	39	30	18	7	1	0
Margarites olivaceus	0	66	20	14	0	0	0	0
Natica clausa	0	25	19	0	19	0	37	0
Polinices pallida	8	9	62	21	0	0	0	0
Cylichna alba	4	25	21	26	10	12	1	1
Echinarachnius parma	46	24	29	1	0	0	0	0
Diamphiodia craterodmeta	0	1	3	79	17	0	0	0
Ophiura sarsi	0	0	13	83	2	0	0	2
Cucumaria calcigera	0	0	98	2	0	0	0	0
Boltenia ovifera	0	0	100	0	0	0	0	0

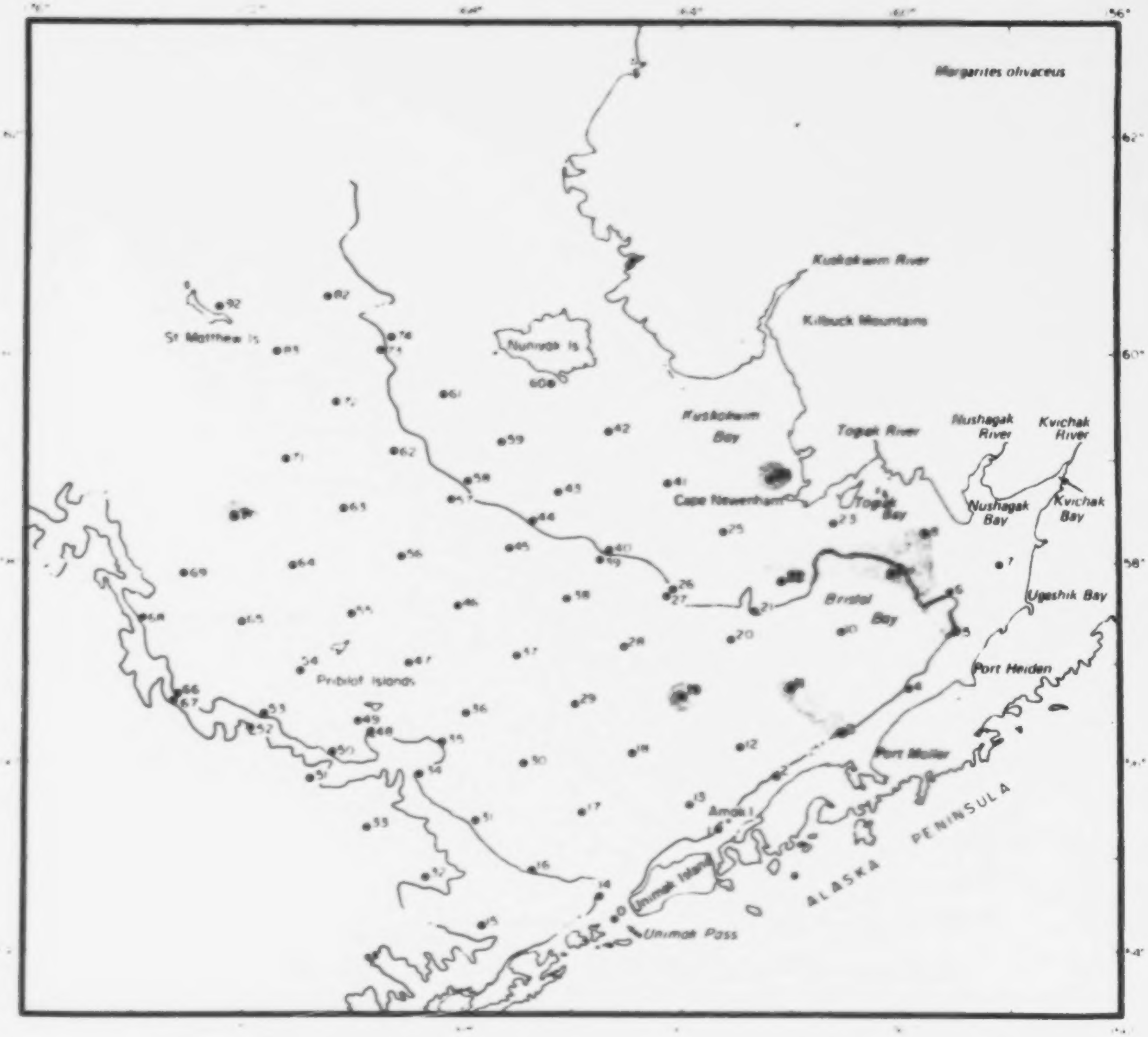

Margarites olivaceus
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
56°
62°
60°
58°
54°

Figure 3.2. Distribution of *Margarites oblivaceus* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

sampled by van Veen grab. The moon snail, *Natica clausa*, was associated with sediment types ranging from very coarse sand to coarse silt (0.0-5.0ϕ; Figs. 2.2-2.6, 3.3; Tables 3.II-3.V). Major Component of Collection: Sixty-three percent (63%) of *N. clausa* occurred in medium sand to coarse silt (2.0-5.0ϕ), with 56% of the gastropods at sediment sorting values of >1.0-4.0. Fifty-six percent (56%) of *N. clausa* occurred from 100-175 m (Appendix 3.D). Minor Component of Collection: Thirty-seven percent (37%) of these gastropods occurred in very coarse to medium sand (0.0-1.0ϕ; Table 3.III), with 24% of the species at sediment sorting values of <.35 and 19% at >.5-.71. Forty-four percent (44%) of *N. clausa* occurred from 25-75 m (medium to fine sand) depths.

The main distribution of the predaceous snail, *Polinices pallida*, was primarily on the southern and eastern portions of the southeastern shelf with small pockets of distribution north and northwest on the shelf (Fig. 3.3). The greatest abundance of this species occurred at Stations 10, 20, 27 and 29 (Appendices 3.A, 3.B). The greatest biomass occurred at Stations 8, 18, 25, 29, 924, 935, and 942 (Appendix 3.C). The snail was present at 32% of the stations sampled by van Veen grab (Appendix 3.A). The moon snail, *Polinices pallida*, was associated with sediment types ranging from medium sand to coarse silt (2.0-5.0ϕ; Figs. 2.2-2.6, 3.3; Tables 3.II-3.V). Major Component of Collection: Seventy-two percent (72%) of *P. pallida* occurred in fine sand to medium silt (2.6-5.0ϕ), with 52% of the gastropods at sediment sorting values of <.35-.71. Sixty-two percent (62%) of *P. pallida* occurred from 50-75 m (Appendix 3.D). Minor Component of Collection: Twenty-eight percent (28%) of these gastropods occurred in medium to fine sand (2.0-2.5ϕ; Table 3.III), with 8% of the species at sediment sorting values of >.71-1.0, 32% at >1.0-2.0 and 8% at >2.0-4.0. Seventeen percent (17%) of *P. pallida* occurred at depths of <25-50 (coarse to medium sand) and 21% at 50-100 m (medium to fine sand).

The bubble snail, *Cylichna alba*, was broadly distributed over the southeastern shelf and extended into the outer and central shelf regions. It was absent over a wide range of stations north, east and southeast of the Pribilof Islands (Fig. 3.4). The greatest abundance of this species occurred at Stations 11, 18, 22, 25, 29, 30, and 49 (Appendices 3.A, 3.B). The

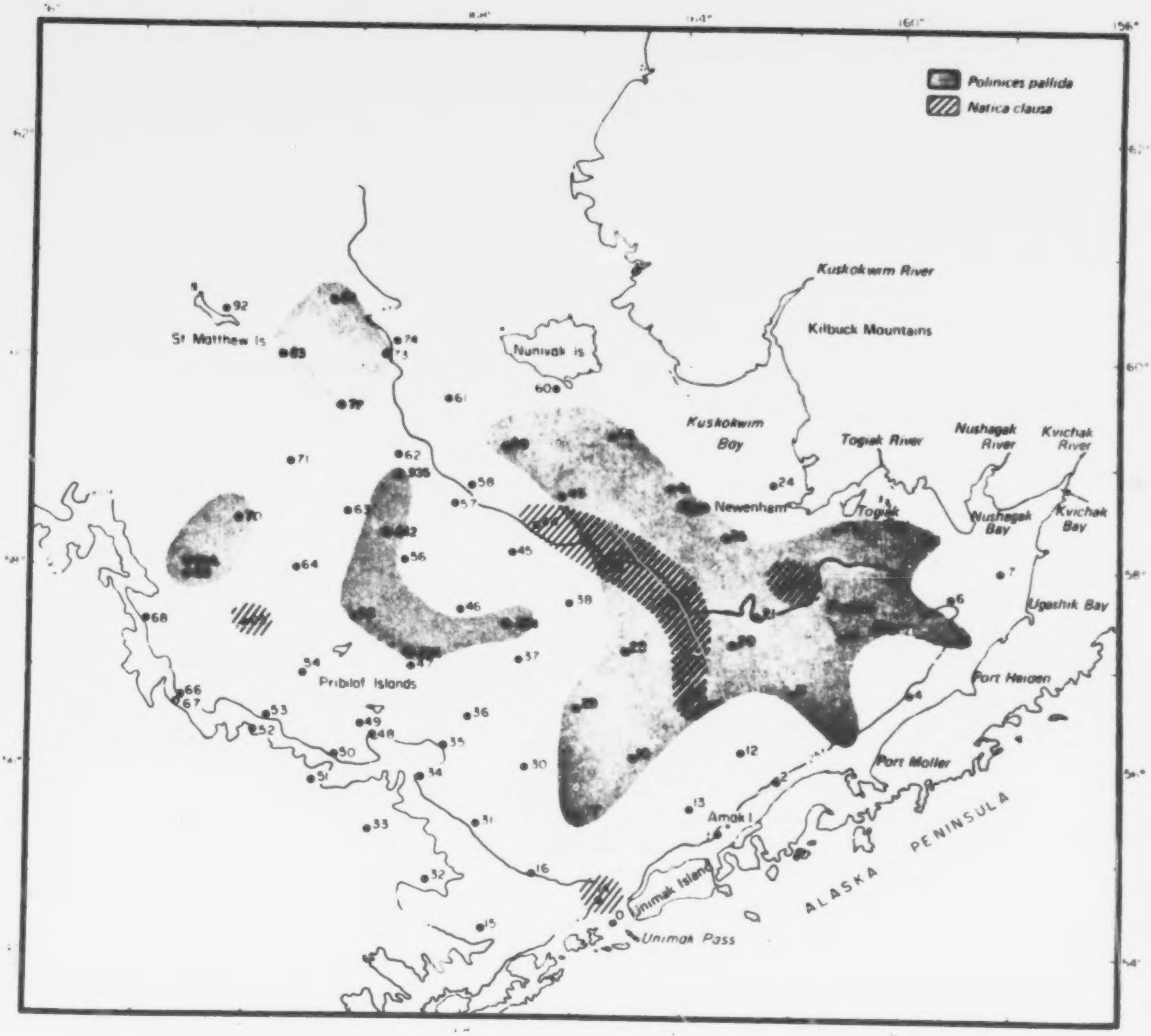

Polinices pallida
Natica clausa
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Newenham
Togiak
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
160°
156°
62°
60°
58°
54°
92
83
74
73
61
60
71
62
58
57
63
64
56
45
46
38
37
68
54
47
66
67
53
52
49
48
50
51
36
35
34
30
24
12
13
33
31
32
16
15
6
7
4
2
0

Figure 3.3. Distribution of *Polinices pallida* and *Natica clausa* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

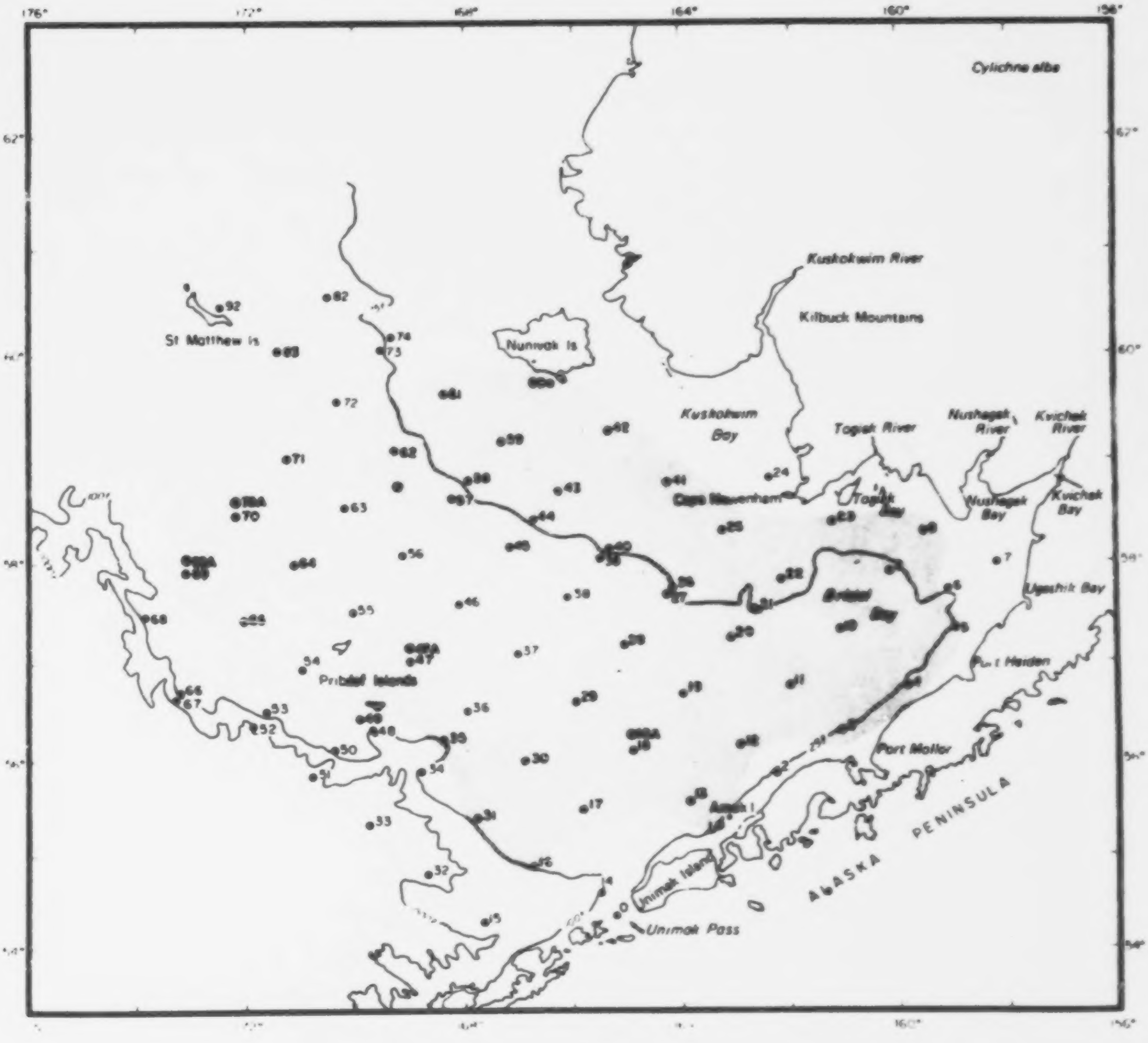

Cylichna alba
St Matthew Is
Nunivak Is
Kuskokwim River
Kilbuck Mountains
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Unimak Island
Unimak Pass
ALASKA PENINSULA
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°

Figure 3.4. Distribution of *Cylichna alba* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

BEST DOCUMENT AVAILABLE

greatest biomass occurred at Stations 18, 25, 29, 30, 41, and 59 (Appendix 3.C). *Cylichna alba* was present at 74% of the stations sampled by van Veen grab (Appendix 3.A). *Cylichna alba* was associated with sediment types ranging from coarse sand to medium silt (1.0-5.0ϕ; Figs. 2.2-2.6, 3.4; Tables 3.II-3.V). Major Component of Collection: Seventy-two percent (72%) of *C. alba* occurred in fine sand to medium silt (3.0-5.0ϕ), with 52% of the gastropods at sediment sorting values of >.71-2.0. Seventy-two percent (72%) of *C. alba* occurred from 25-100 m (Appendix 3.C). Minor Component of Collection: Two percent (2%) of these gastropods occurred in coarse to medium sand (1.0-2.3ϕ), and 22% in medium silt (5.0ϕ; Table 3.III), with 18% of the species at sediment sorting values of <.35, 3% at .35-.71, 9% at >.71-1.0 and 8% at >2.0-4.0. Four percent (4%) of *C. alba* occurred at depths of <25 m (coarse to medium sand), 22% at 100-150 m (medium silt) and 2% at 150->175 m (medium silt).

The sand dollar, *Echinarachnius parma*, occurred inshore from south of Nunivak Island through Bristol Bay and along the Alaska Peninsula. A small pocket of individuals occurred northeast of the Pribilof Islands (Fig. 3.5). The greatest abundance of this species occurred at Stations 6, 7, 8, 9, 22, 23, and 60 (Appendices 3.A, 3.B). The gratest biomass occurred at Stations 5, 6, 7, 10, 19, 22, and 23 (Appendix 3.C). The sand dollar was present at 32% of the stations sampled by van Veen grab (Appendix 3.A). *Echinarachnius parma* was associated with sediment types ranging from very coarse sand to medium silt (-0.77-5.0ϕ; Figs. 2.2-2.6, 3.5; Tables 3.II-3.V). Major Component of Collection: Sixty-nine percent (69%) of *E. parma* occurred in medium to fine sand (2.0-3.0ϕ), with 72% of the sand dollars at sediment sorting values of .35-.71. Seventy percent ((70%) of *E. parma* occurred from <25-50 m (Appendix 3.D). Minor Component of Collection: Eighteen percent (18%) of the sand dollars occurred in very coarse to medium sand (-0.77-2.0ϕ) and 13% in very fine sand to medium silt (4.0-5.0ϕ; Table 3.III) with 5% of the species at sediment sorting values of <.35 and 23% at >1.0-2.0. Thirty percent (30%) of *E. parma* occurred at depths of 50-100 m (very fine sand to medium silt).

The brittle star, *Diamphiodia craterodmeta*, was widely distributed over the mid-portion of the southeastern shelf, and extended to the outer

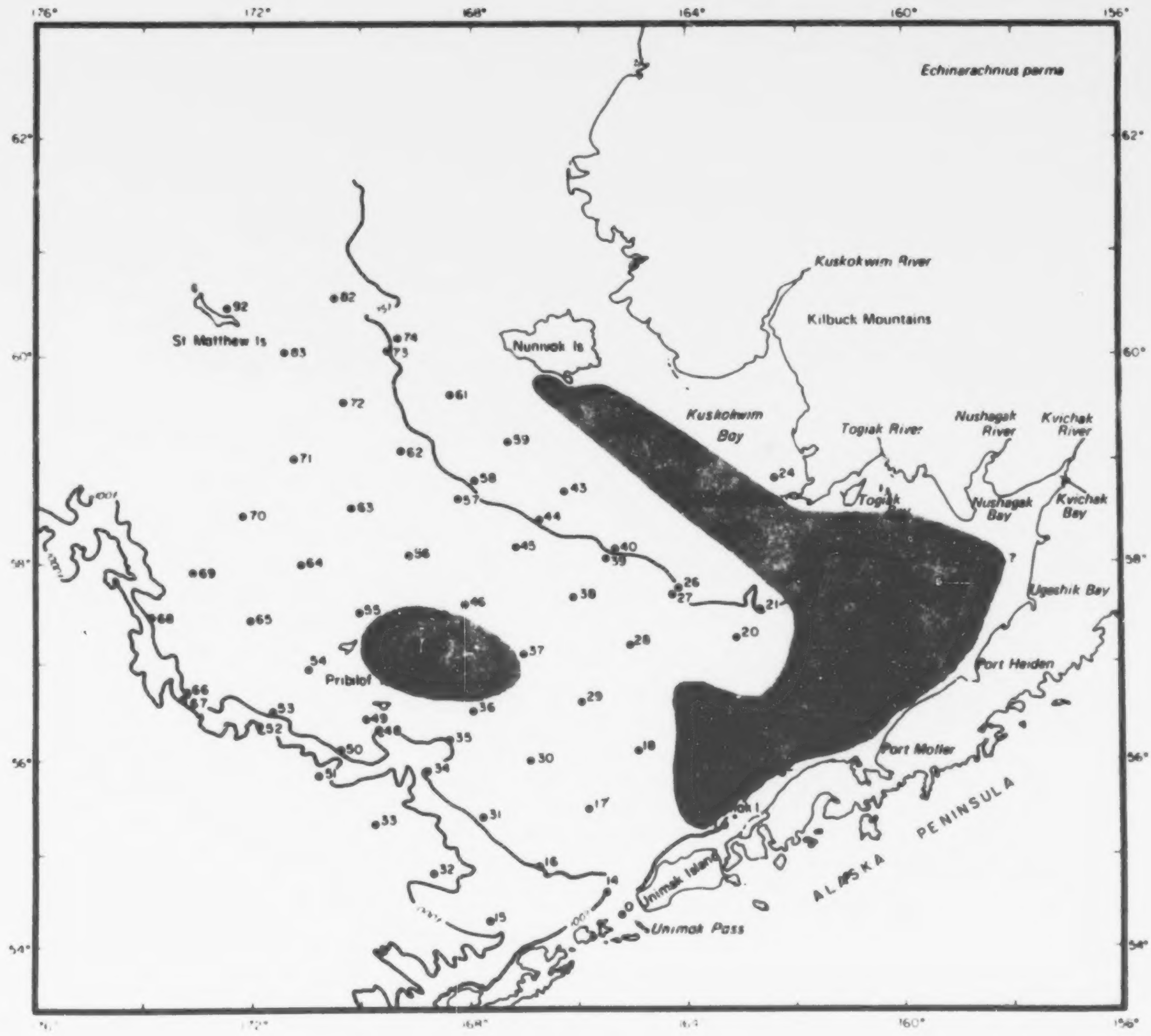

Echinarachnius parma
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 3.5. Distribution of *Echinarachnius parma* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

BEST DOCUMENT AVAILABLE

shelf north and south (Fig. 3.6). The greatest abundance of this species occurred at Stations 17, 18, 19, 29, 47, 64, and 70 (Appendices 3.A, 3.B). The greatest biomass occurred at Stations 1, 18, 19, 29, 47, 64, and 70 (Appendix 3.C). The brittle star was present at 42% of the stations sampled by van Veen grab (Appendix 3.A). *Diamphiodia craterodmeta* was associated with sediment types ranging from fine sand to medium silt (2.3-5.7ϕ; Figs. 2.2-2.6, 3.6; Tables 3.II-3.V). Major Component of Collection: Eighty-six percent (86%) of *D. craterodmeta* occurred in fine sand to medium silt (3.0-5.0ϕ), with 88% of the brittle stars at sediment sorting values of >1.0-2.0. Seventy-nine percent (79%) of *D. craterodmeta* occurred from 50-100 m (Appendix 3.D). Minor Component of Collection: Fourteen percent (14%) of these brittle stars occurred in medium silt (5.1-5.7ϕ; Table 3.III), with 1% of the species at sediment sorting values of .71-1.0 and 11% at 2.0-4.0. Four percent (4%) of *D. craterodmeta* occurred at depths of 25-75 m (medium to fine sand) and 17% at 100-125 m (medium silt).

The brittle star, *Ophiura sarsi*, occurred on the mid-portion of the southern portion of the southeastern shelf and along the outer shelf (Fig. 3.7). The greatest abundance of this species occurred at Stations 16, 19, 28, 29 and 47 (Appendices 3.A, 3.B). The greatest biomass occurred at Stations 19, 28, 29, and 47 (Appendix 3.C). The brittle star was present at 19% of the stations sampled by van Veen grab (Appendix 3.A). *Ophiura sarsi* was associated with sediment types ranging from fine sand to medium silt (2.3-5.7ϕ; Figs. 2.2-2.6, 3.7; Tables 3.II-3.V). Major Component of Collection: Eighty-two percent (82%) of *O. sarsi* occurred in fine to very fine sand (3.0-4.0ϕ), with 97% of the brittle stars at sediment sorting values of >1.0-2.0. Eighty-three percent (83%) of *O. sarsi* occurred from 50-100 m (Appendix 3.D). Minor Component of Collection: Two percent (2%) of the brittle stars occurred in fine sand (2.0-3.0ϕ) and 16% in medium silt (5.0-5.7ϕ; Table 3.III), with 2% of the species at sediment sorting values of .35-.71 and 1% at >2.0-4.0. Thirteen percent (13%) of *O. sarsi* occurred at depths of 50-75 m (medium to fine sand) and 2% at 100-125 m (medium silt) amd 2% at >175 m (medium silt).

The sea cucumber, *Cucumaria calcigera*, had a very limited and patchy distribution on the southeastern shelf (Fig. 3.8). The greatest abundance

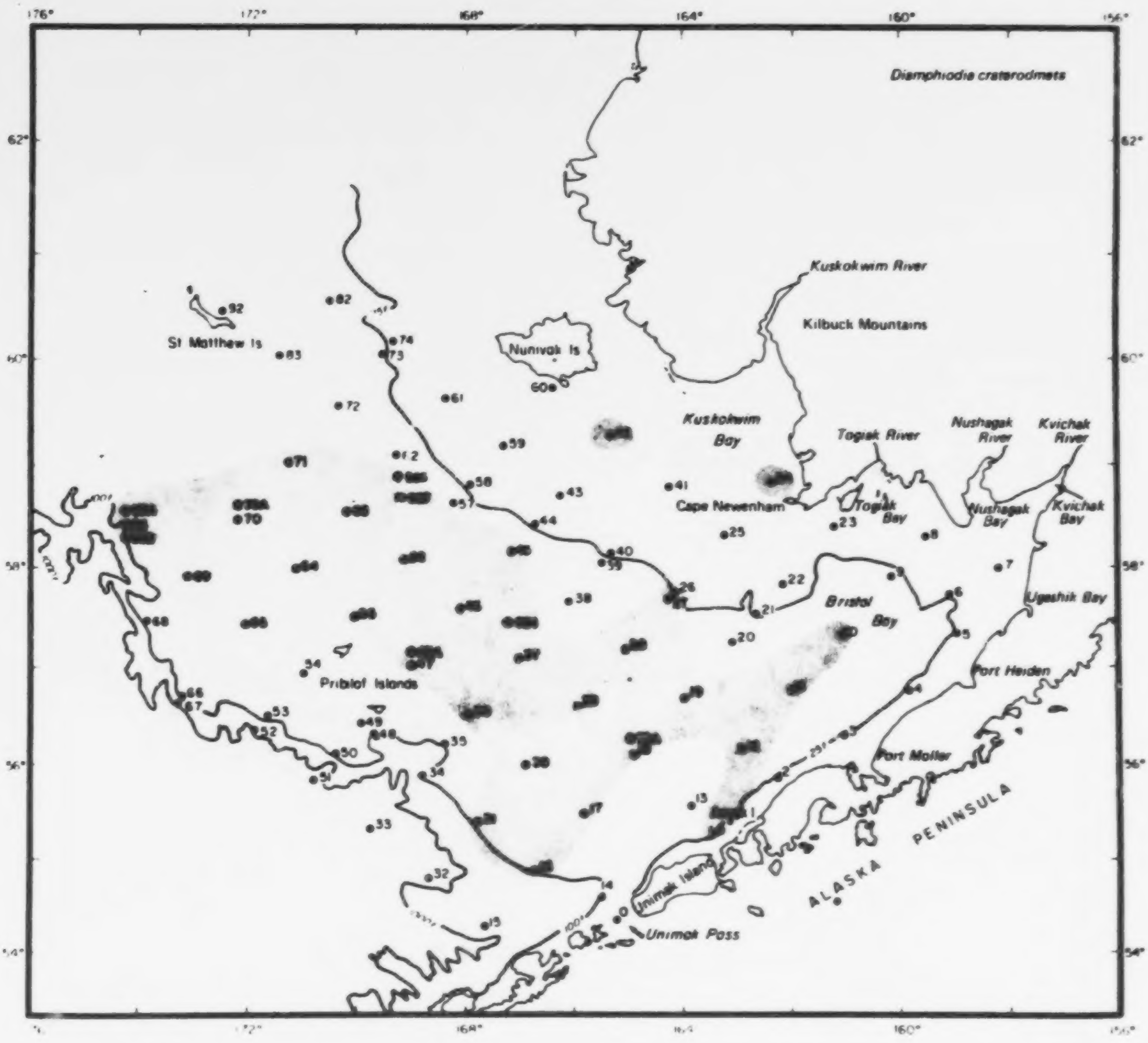

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Diamphiodia craterodmeta
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Pribilof Islands
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
83
74
73
72
61
60
59
58
57
43
44
41
40
39
25
23
8
7
22
21
20
6
5
38
54
53
52
66
67
68
70
49
48
50
51
35
34
33
32
15
14
13
17
30

Figure 3.6. Distribution of *Diamphiodia craterodmeta* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

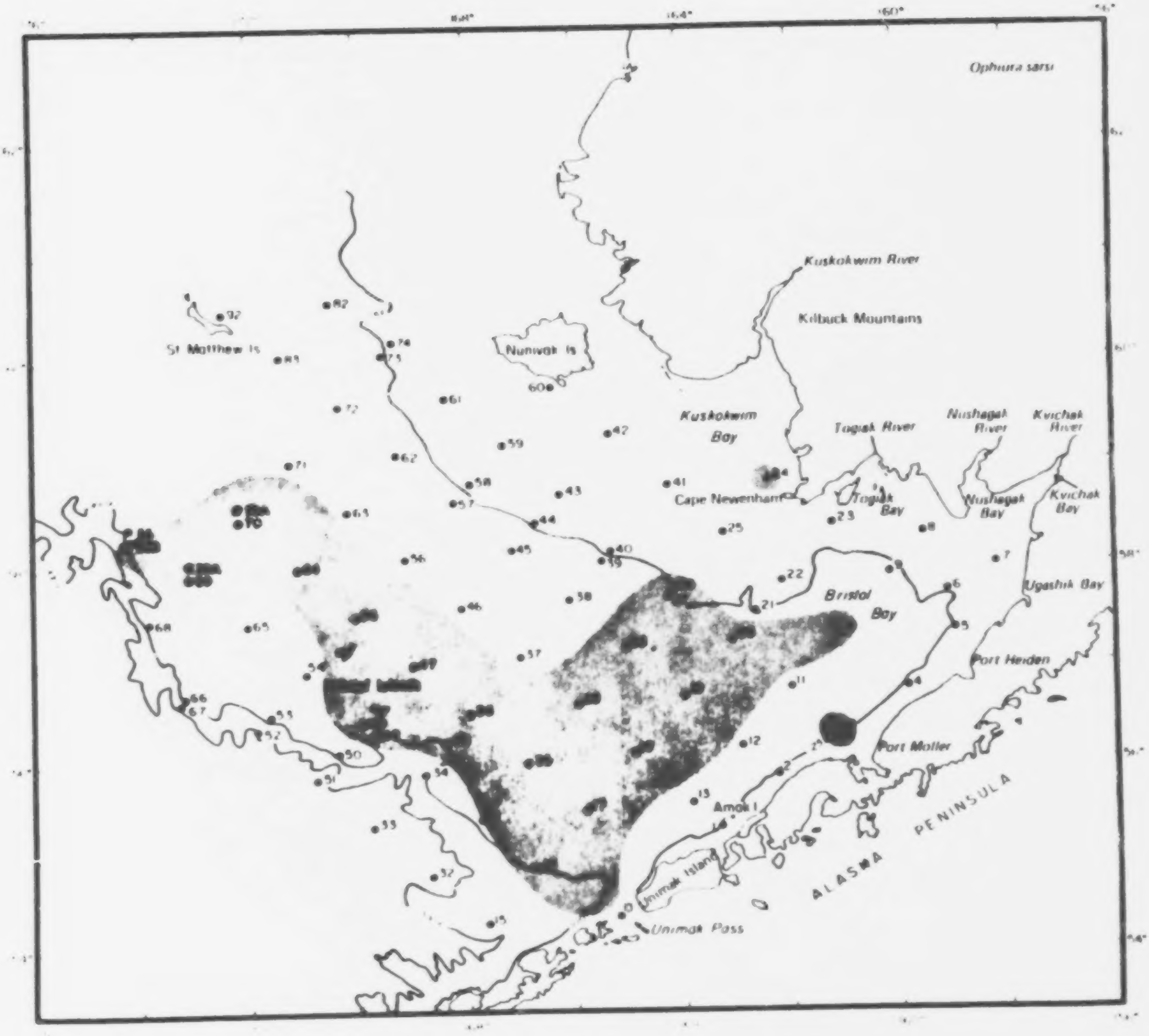

Ophiura sarsi
168°
164°
160°
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 3.7. Distribution of *Ophiura sarsi* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

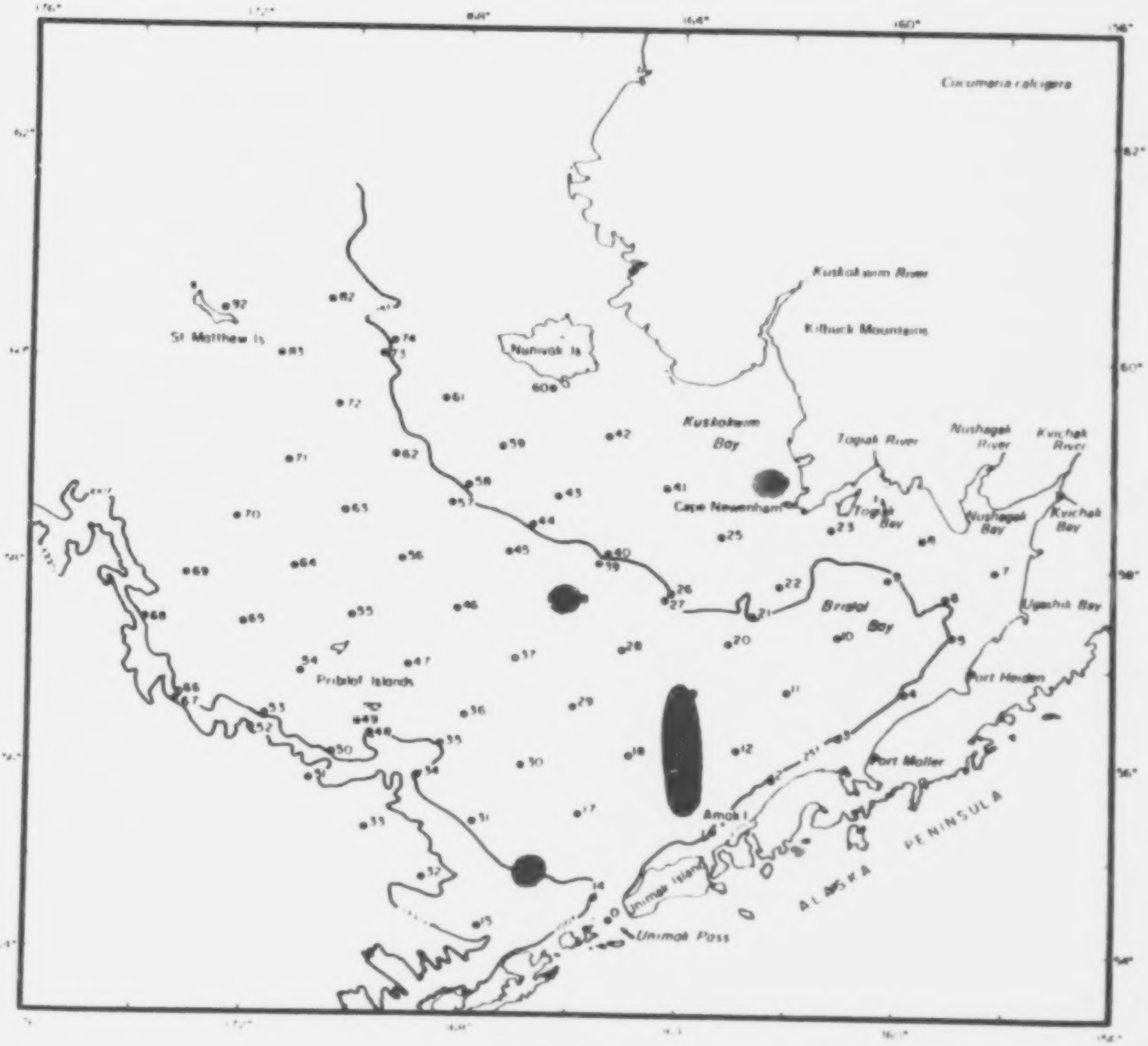

Cucumaria calcigera
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
62°
60°
58°
56°
54°
160°
164°
168°
172°
176°

Figure 3.8. Distribution of *Cucumaria calcigera* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

of this species occurred at Station 38 (Appendices 3.A, 3.B). The greatest biomass occurred at Stations 19 and 38 (Appendix 3.C). *Cucumaria calcigera* was present at 7% of the stations sampled by van Veen grab (Appendix 3.A). *Cucumaria calcigera* was associated with sediment types ranging from coarse sand to medium silt (1.0-5.0ϕ; Figs. 2.2-2.6, 3.8; Tables 3.II-3.V). Major Component of Collection: Ninety-eight percent (98%) of *C. calcigera* occurred in very fine to coarse silt (4.0-5.0ϕ), with 99% of the sea cucumbers at sediment sorting values of >1.0-2.0. Ninety-eight percent (98%) of *C. calcigera* occurred at depths of 50-75 m. Minor Component of Collection: Two percent (2%) of the sea cucumbers occurred in fine to very fine sand (3.0-4.0ϕ; Table 3.III) with 1% of this species at sediment sorting values of >2.0-4.0. Two percent (2%) of *C. calcigera* occurred at depths of 75-100 m (fine sand).

The tunicate, *Boltenia ovifera*, was found primarily inshore in the eastern portion of the southeastern shelf. The species occurred at two additional areas as well, east of St. Matthew Island and north of the Pribilof Islands (Fig. 3.9). The greatest abundance of this species, as determined by pipe dredge, occurred at Stations 4, 5 and 25 (Appendices 3.A, 3.B). The greatest biomass occurred at Station 4 for both the grab and pipe dredge (Appendix 3.C). *B. ovifera* was present at 7% of the stations sampled by pipe dredge and 2% by grab. *B. ovifera* was associated with sediment types ranging from very coarse sand to medium silt (1.0-5.7ϕ; Figs. 2.2-2.6, 3.9; Tables 3.II-3.V). Major Component of Collection: One hundred percent (100%) of *B. ovifera* occurred in coarse to medium sand (0.0-1.0ϕ), with 100% of the tunicates at sediment sorting values of >1.0-2.0. One hundred percent (100%) of *B. ovifera* occurred at depths of 50-75 m.

Density and Biomass

Common infauna (exclusive of clams), and sessile and slow-moving epifauna (mixed species) were most numerous at stations on the outer portion of the southeastern Bering Sea shelf (Figs. 2.1, 2.7; Table 3.VI) as for example Station 47 with 658 indiv/m², and Station 30 with 106 indiv/m². Large numbers were also found at Stations 7, 8, 9, and 60 (111, 582, 376, and 126 individuals, respectively) on the inshore portion and Stations 18, 29, and 38 (274, 250, and 260 individuals, respectively) on the mid-shelf portion.

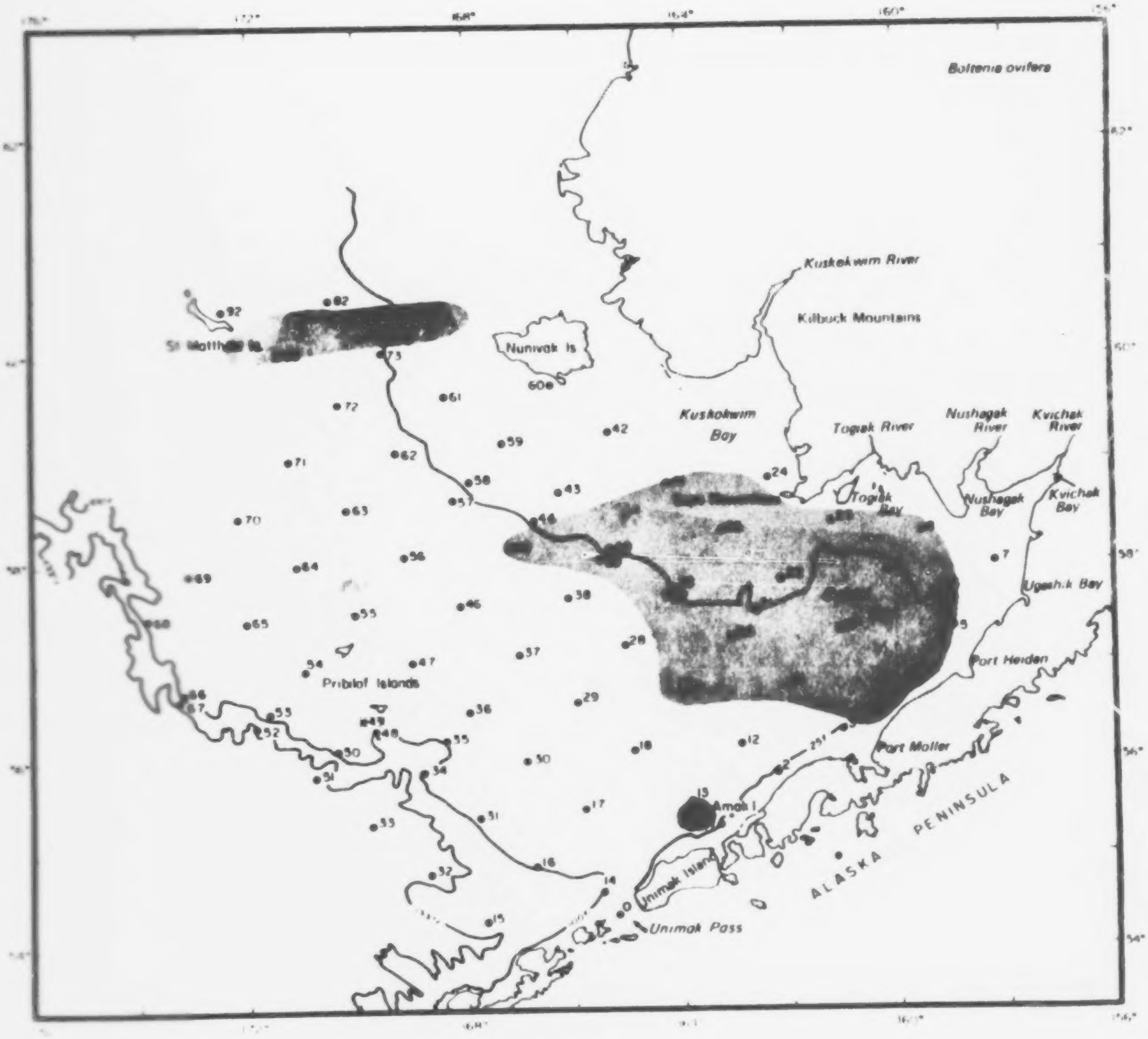

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Boltenia ovifera
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
92
82
73
72
61
60
42
59
62
71
58
43
24
57
44
70
63
56
64
69
38
46
55
65
68
28
7
54
47
37
29
66
67
53
52
49
48
36
35
30
50
51
34
18
12
13
17
31
33
32
16
14
15

Figure 3.9. Distribution of *Boltenia ovifera* based on collections taken with a grab, pipe dredge, clam dredge and otter trawl.

TABLE 3.VI

TOTAL NUMBER OF COMMON INVERTEBRATES/M^2 BY STATION ON THE SOUTHEASTERN BERING SEA SHELF

Table based on data in Appendix 3.A

Station	Total No/m^2	Station	Total No/m^2	Station	Total No/m^2
1	16	23	58	49	39
3	26	24	17	55	16
4	50	25	90	57	19
5	95	27	30	59	43
6	70	28	46	60	126
7	111	29	250	61	16
8	582	30	106	62	36
9	576	31	8	64	78
10	48	35	4	65	30
11	66	36	80	70	123
12	36	37	12	71	22
13	21	38	260	72	4
14	4	39	4	73	12
16	26	40	12	82	4
17	78	41	20	83	4
18	274	42	30	924	8
19	258	43	10	935	50
20	36	45	8	937	6
22	106	47	658	942	3

Eight of the 11 common species collected in the southeastern Bering Sea were each found in over 11% of the stations sampled by grab (Appendix 3.A): *Cylichna alba* (74% of the stations sampled), *Solariella obscura* (54%), *Diamphiodia craterodmeta* (42%), *Solariella varicosa* (32%), *Echinarachnius parma* (32%), *Polinices pallida* (32%), *Ophiura sarsi* (19%) and *Margarites olivaceus* (11%).

Common infauna (not including bivalve molluscs), sessile and slow-moving epifauna (mixed species) biomass was greatest at stations on the mid-shelf portion of the southeastern Bering Sea shelf (Figs. 2.1, 2.7; Table 3.VII), as for example, Station 38 with 631.7 g/m^2, Station 19: 83.9 g/m^2 and Station 28: 49.2 g/m^2. Large biomass values were also noted on the inshore portion of the shelf at Station 4: 212.7 g/m^2, Station 7: 189.2 g/m^2, Station 6: 108.1 g/m^2 and Station 5: 87.1 g/m^2.

VII. DISCUSSION

Although the epifaunal and infaunal species of the southeastern Bering Sea shelf exhibit patchy distributions (McLaughlin, 1963; Stoker, 1973, 1978; Shevtsov, 1964; Haflinger, 1978; Section 1 of this report, and NODC data on file), it is often possible to predict their occurrence based on associated sediment particle size and sediment sorting (Sanders, 1958, 1960; Stoker, 1973, 1978; Shevtsov, 1964), and depth. The data presented in this section suggest that, in general, the distribution of the infaunal species discussed in this section are associated with specific sediment size, sorting range, and depth.

Solariella obscura, *Polinices pallida*, *Natica clausa*, *Cylichna alba*, *Diamphiodia craterodmeta* and *Ophiura sarsi* exhibited the widest distributions, and occurred from inshore to approximately 175 m, while *Margarites olivaceus*, *Echinarachnius parma* and *Boltenia ovifera* distributions were generally confined inshore to depths of 25-75 m. *Solariella varicosa* and *Cucumaria calcigera* were generally confined to the mid-shelf area. The depth distributions of all species included in this report overlapped extensively. *Diamphiodia craterodmeta* occurred primarily in fine sand to medium silt, and *Ophiura sarsi* occurred on fine to very fine sand. *Polinices pallida* and *Solariella varicosa* occurred on fine sand to medium silt while *S. obscura*

TABLE 3.VII

G/M^2 BY STATION ON THE SOUTHEASTERN BERING SEA SHELF

Table based on data in Appendix 3.C

Station	g/m^2	Station	g/m^2	Station	g/m^2
1	9.87	23	44.05	49	.36
3	1.46	24	.40	55	.06
4	212.72	25	4.07	57	.70
5	87.09	27	6.37	59	3.02
6	108.11	28	49.18	60	3.92
7	189.22	29	34.66	61	1.25
8	9.20	30	1.48	62	1.12
9	4.35	31	.27	64	3.63
10	81.17	35	.19	65	.22
11	8.11	36	1.50	70	4.39
12	7.98	37	.53	71	.14
13	.54	38	631.65	72	.34
14	.47	39	.02	73	.37
16	1.28	40	.41	82	.21
17	.43	41	.90	83	.38
18	8.26	42	1.36	924	10.49
19	83.85	43	.08	935	6.48
20	1.90	45	.28	937	.01
22	17.70	47	15.27	942	8.683

was found on medium sand to coarse silt. *Cylichna alba, Margarites olivaceus, Natica clausa* and *Cucumaria calcigera* occurred on coarse sand to medium silt. *Echinarachnius parma* and *Boltenia ovifera* occurred in very coarse sand to medium silt.

Boltenia ovifera and *Cucumaria calcigera* are suspension feeders (see Bering Sea classification of invertebrate feeding types by Filatova and Barsanova 1964; also refer to Feder and Matheke, 1979), and utilize phytoplankton and probably detrital material from several centimeters above the water-sediment interface (also see Hoskin *et al.*, 1976; Hoskin, 1977; and Mueller *et al.*, 1976, for discussions on use of bottom materials by suspension feeders). This trophic group typically inhabits areas of moderate circulation and medium to high suspended load on coarse to fine sand (-.5-3.0ϕ) and medium silt (5.0-5.7ϕ) between 25-75 m (Kuznetsov, 1964).

Three species - *Echinarachnius parma, Diamphiodia craterodmeta* and *Ophiura sarsi* - are classified with the major trophic group of detrital feeders as described by Kuznetsov (1964) and Filatova and Barsanova (1964). This group includes those organisms capable of selectively removing particulate material from the sediment surface. The group typically inhabits areas of weak circulation and moderate sedimentation, usually on fine sand (2.0-3.0ϕ) and coarse silt (4.0-5.0ϕ) between 50-100 m (Kuznetsov, 1964). While *O. sarsi* is a detrital feeder, it can supplement as a predator (Feder, unpub. OCSEAP data).

The predatory gastropods - *Polinices pallida, Natica clausa, Solariella obscura, S. varicosa, Cylichna alba* and *Margarites olivaceus* - comprise a trophic group that is ubiquitous, inhabiting all of the southeastern Bering Sea shelf. While *P. pallida* and *N. clausa* are exclusively predators, the remaining species supplement as scavengers (Filatova and Barsanova, 1964).

VIII. CONCLUSIONS

The lowest densities of the 11 species considered in this report, occurred in the mid-portion of the southeastern Bering Sea shelf at intermediate depths in very coarse to fine sand (<0-3.0ϕ) with moderately to poorly sorted sediments ($>.71-2.0\delta_I$) while the biomass was highest. The greatest numbers occurred in the outer portion in deep water in fine sand to medium silt ($>3.0-6.0\phi$) with moderately to very poorly sorted sediments ($>.71-4.0\delta_I$) and high organic carbon content, while the biomass was lowest (see Discussion, Section 2).

The distributions of the 11 invertebrate species overlapped extensively. *Solariella obscura* occurred at depths of 25-175 m with 82% between <25-75 m; *S. varicosa* occurred at depths of 25-175 m with 75% between 50-100 m; *Margarites olivaceus* occurred at depths of 25-100 m with 66% between 25-50 m; *Natica clausa* occurred at depths of 25-175 m with 56% between 100-175 m; *Polinices pallida* occurred in depths of <25-100 m with 62% between 50-75 m. *Cylichna alba* occurred in depths of <25->175 m with 72% at 25-100 m; *Echinarachnius parma* occurred in depths of <25-100 m with 99% at <25-75 m; *Diamphiodia craterodmeta* occurred at depths of 25-125 m with 79% between 75-100 m; *Ophiura sarsi* occurred in depths of 50-125 m with 83% between 50-100 m; *Cucumaria calcigera* occurred at depths of 25-100 m with 98% between 50-75 m; *Boltenia ovifera* occurred at depths of 50-75 m with 100% between 50-75 m.

The sediment range for the invertebrate species examined was as follows: *Solariella obscura* in very coarse sand to medium silt with 59% in medium to fine sand; *S. varicosa* in fine sand to medium silt with 64% in fine to very fine sand; *Margarites olivaceus* in coarse sand to medium silt with 80% in medium to fine sand; *Natica clausa* in very coarse sand to coarse silt with 63% in medium sand to coarse silt; *Polinices pallida* in medium sand to coarse silt with 72% in fine sand to coarse silt; *Cylichna alba* in coarse sand to medium silt with 98% in medium sand to medium silt; *Echinarachnius parma* in very coarse sand to coarse silt with 69% in medium to fine sand; *Diamphiodia craterodmeta* in fine sand to medium silt with 86% in fine sand to coarse silt; *Ophiura sarsi* in fine sand to coarse silt with 82% in fine to very fine sand; *Cucumaria calcigera* in coarse sand to medium silt with 98% in very fine sand to coarse silt; *Boltenia ovifera* in coarse to medium sand with 100% in coarse to medium sand.

The sediment sorting for the invertebrate species also overlapped extensively. *Solariella obscura* in very well to very poorly sorted sediments with 52% within very well to moderately well sorted sediments; *S. varicosa* in well to very poorly sorted with 67% within poorly sorted sediments; *Margarites olivaceus* in very well to very poorly sorted with 79% within poorly sorted sediments; *Natica clausa* in very well to very poorly sorted with 56% within poorly to very poorly sorted sediments; *Polinices pallida* in very well to poorly sorted with 52% within very well to moderately sorted sediments; *Cylichna alba* in very well to very poorly sorted with 62% within moderately to poorly sorted sediments; *Echinarachnius parma* in very well to poorly sorted with 72% within well to moderately sorted sediments; *Diamphiodia craterodmeta* in very well to poorly sorted with 88% within poorly sorted sediments; *Ophiura sarsi* in well to poorly sorted with 97% within poorly sorted sediments; *Cucumaria calcigera* in poorly to very poorly sorted with 99% within poorly sorted sediments; *Boltenia ovifera* in poorly sorted with 100% within poorly sorted sediments.

See general comments in Sections 1 and 2 on biological monitoring of infauna of the southeastern Bering Sea shelf.

APPENDIX 3.A

SOUTHEASTERN BERING SEA GRAB DATA 1975
THE DENSITY (COUNTS/M^2) OF DOMINANT INFAUNAL SPECIES COLLECTED BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA

(See Fig. 2.7 for station locations)

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	1	3	4	5	6	7	8	9
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	27	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYLICHNA ALBA	COUNTS/METER SQUARED	6	16	3	5	0	0	6	10
DIAMPHIODIA CRATERODMETA	COUNTS/METER SQUARED	10	0	0	0	0	0	0	0
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	0	6	20	30	70	111	504	356
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	0	0	0	55	0	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
POLINICES PALLIDA	COUNTS/METER SQUARED	0	0	0	0	0	0	4	0
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	0	4	0	5	0	3	68	10
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0

	STATIONS	10	11	12	13	14	16	17	18
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0	0	0	0	0	2	0	0
CYLICHNA ALBA	COUNTS/METER SQUARED	26	40	12	17	0	6	24	46
DIAMPHIODIA CRATERODMETA	COUNTS/METER SQUARED	0	4	4	0	0	6	50	210
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	6	4	18	2	0	0	0	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	2	12	0	0	0	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	0	0	4	0	0	0
OPHIURA SARSI	COUNTS/METER SQUARED	6	0	0	0	0	12	2	0
POLINICES PALLIDA	COUNTS/METER SQUARED	8	4	0	0	0	0	0	4
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	0	2	2	0	0	0	2	6
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	0	0	0	2	0	0	0	8

	STATIONS	19	20	22	23	24	25	27	28
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	4	0	0	0	3	0	0	0
CYLICHNA ALBA	COUNTS/METER SQUARED	0	12	21	8	0	66	12	2
DIAMPHIODIA CRATERODMETA	COUNTS/METER SQUARED	202	0	0	0	8	0	0	8
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	2	0	46	46	0	21	0	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	12	0	1	0	3	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	3	0	0	0	2	0
OPHIURA SARSI	COUNTS/METER SQUARED	26	4	0	0	3	0	0	34
POLINICES PALLIDA	COUNTS/METER SQUARED	4	10	0	0	0	3	6	0
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	4	4	35	4	0	0	12	2
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	4	6	0	0	0	0	0	0

	STATIONS	29	30	31	35	36	37	38	39
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0	0	0	0	0	0	258	0
CYLICHNA ALBA	COUNTS/METER SQUARED	100	94	4	2	4	0	0	0
DIAMPHIODIA CRATERODMETA	COUNTS/METER SQUARED	122	0	3	0	38	8	0	0
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNTS/METER SQUARED	16	0	0	0	6	0	0	0
POLINICES PALLIDA	COUNTS/METER SQUARED	8	0	0	0	0	0	0	0
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	2	2	0	2	8	4	0	4
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	2	10	1	0	24	0	2	0

BEST DOCUMENT AVAILABLE

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	40	41	42	43	45	49	57	59
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYLICHNA ALBA	COUNTS/METER SQUARED	5	17	20	10	1	37	3	38
DIAPHIODIA CRATERODMETA	COUNTS/METER SQUARED	0	0	2	0	1	0	0	0
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	0	3	4	0	0	0	0	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
POLINICES PALLIDA	COUNTS/METER SQUARED	2	0	2	0	0	0	0	0
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	0	0	2	0	3	0	13	5
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	5	0	0	0	3	2	3	0

	STATIONS	60	61	62	64	65	924	935	937
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYLICHNA ALBA	COUNTS/METER SQUARED	1	4	2	16	2	0	0	2
DIAPHIODIA CRATERODMETA	COUNTS/METER SQUARED	0	0	0	62	26	4	2	2
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	121	0	0	0	0	0	0	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	0	0	2	0	0	0
OPHIURA SARSI	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
POLINICES PALLIDA	COUNTS/METER SQUARED	0	0	0	0	0	4	2	0
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	4	12	30	0	0	0	12	0
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	0	0	4	0	0	0	34	2

	STATIONS	942	47	55	70	71	72	73	82
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
CYLICHNA ALBA	COUNTS/METER SQUARED	0	6	0	3	2	0	0	0
DIAPHIODIA CRATERODMETA	COUNTS/METER SQUARED	0	288	8	120	20	0	0	0
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
NATICA CLAUSA	COUNTS/METER SQUARED	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNTS/METER SQUARED	0	314	8	0	0	0	0	0
POLINICES PALLIDA	COUNTS/METER SQUARED	3	0	0	0	0	4	2	4
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	0	20	0	0	0	0	8	0
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	0	30	0	0	0	0	2	0

	STATIONS	83
BOLTENIA OVIFERA	COUNTS/METER SQUARED	0
CUCUMARIA COLCIGERA	COUNTS/METER SQUARED	0
CYLICHNA ALBA	COUNTS/METER SQUARED	2
DIAPHIODIA CRATERODMETA	COUNTS/METER SQUARED	0
ECHINARACHNIUS PARMA	COUNTS/METER SQUARED	0
MARGARITES OLIVACEUS	COUNTS/METER SQUARED	0
NATICA CLAUSA	COUNTS/METER SQUARED	0
OPHIURA SARSI	COUNTS/METER SQUARED	0
POLINICES PALLIDA	COUNTS/METER SQUARED	2
SOLARIELLA OBSCURA	COUNTS/METER SQUARED	0
SOLARIELLA VARICOSA	COUNTS/METER SQUARED	0

APPENDIX 3.B

SOUTHEASTERN BERING SEA PIPE DREDGE DATA 1975

SOUTHEASTERN BERING SEA PIPE DREDGE DATA 1975

	STATIONS	0001	0002	0003	0004	0005	0006	0007	0008	0009	0010	0011
SOLARIELLA OBSCURA	COUNT	0	2	0	6	0	0	0	0	6	1	0
S.VARICOSA	COUNT	0	0	0	0	0	0	0	0	0	0	0
MARGARITES OLIVACEUS	COUNT	0	0	0	16	0	0	0	0	1	0	0
NATICA CLAUSA	COUNT	0	0	2	0	0	0	0	0	0	0	0
POLINICES PALLIDA	COUNT	0	0	0	6	0	0	1	0	1	1	1
CYLICHNA ALBA	COUNT	0	3	0	1	0	0	0	0	0	1	0
ECHINARACHNIUS PARMA	COUNT	0	16	0	50	1	20	35	40	0	75	0
DIAMPHIODIA CRATERODMETA	COUNT	0	0	0	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNT	0	0	0	1	0	0	0	0	0	0	0
CUCUMARIA CALCIGERA	COUNT	15	0	0	0	0	0	0	0	0	0	0
BOLTENIA OVIFERA	COUNT	0	0	0	0	45	6	5	0	0	0	0

	STATIONS	0013	0014	0015	0016	0017	0018	0019	0020	0021	0022	0023
SOLARIELLA OBSCURA	COUNT	0	0	17	0	2	0	0	2	0	0	23
S.VARICOSA	COUNT	0	0	0	0	0	0	0	0	0	20	0
MARGARITES OLIVACEUS	COUNT	0	0	2	0	2	1	0	0	0	0	0
NATICA CLAUSA	COUNT	0	0	0	0	0	1	0	0	0	0	0
POLINICES PALLIDA	COUNT	6	0	1	2	0	0	2	2	0	0	2
CYLICHNA ALBA	COUNT	12	9	3	1	2	0	12	3	0	40	0
ECHINARACHNIUS PARMA	COUNT	1	0	15	3	4	0	0	0	0	0	0
DIAMPHIODIA CRATERODMETA	COUNT	0	0	0	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNT	0	0	0	0	0	54	0	0	6	0	0
CUCUMARIA CALCIGERA	COUNT	0	0	0	0	0	1	0	0	0	0	0
BOLTENIA OVIFERA	COUNT	0	1	0	0	0	0	0	0	0	0	0

	STATIONS	0024	0025	0026	0027	0028	0029	0030	0032	0033	0034	0035
SOLARIELLA OBSCURA	COUNT	0	0	0	0	0	0	9	14	0	0	0
S.VARICOSA	COUNT	0	0	0	0	0	0	10	24	1	1	1
MARGARITES OLIVACEUS	COUNT	0	0	0	0	5	2	0	0	0	0	0
NATICA CLAUSA	COUNT	0	0	0	0	0	0	1	0	0	0	0
POLINICES PALLIDA	COUNT	0	0	3	0	3	4	0	1	0	0	0
CYLICHNA ALBA	COUNT	4	0	1	0	14	100	0	6	0	0	0
ECHINARACHNIUS PARMA	COUNT	0	0	0	0	0	0	0	2	0	0	0
DIAMPHIODIA CRATERODMETA	COUNT	0	0	0	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNT	1	65	4	200	4	26	0	0	0	0	0
CUCUMARIA CALCIGERA	COUNT	0	0	0	0	0	0	0	0	0	180	114
BOLTENIA OVIFERA	COUNT	0	0	0	0	0	0	0	0	0	0	0

SOUTHEASTERN BERING SEA PIPE DREDGE DATA 1975

	STATIONS	0036	0037	0038	0039	0040	0041	0042	0043	0044
SOLARIELLA OBSCURA	COUNT	15	1	1	9	14	12	0	5	4
S.VARICOSA	COUNT	0	0	0	0	0	0	0	0	2
MARGARITES OLIVACEUS	COUNT	0	0	0	0	0	0	0	0	0
NATICA CLAUSA	COUNT	3	0	0	1	1	17	2	0	0
POLINICES PALLIDA	COUNT	4	6	1	0	3	28	0	1	0
CYLICHNA ALBA	COUNT	2	35	8	1	0	4	2	2	10
ECHINARACHNIUS PARMA	COUNT	0	0	0	0	0	2	0	0	0
DIAMPHIODIA CRATERODMETA	COUNT	0	0	0	0	0	0	0	0	0
OPHIURA SARSI	COUNT	0	0	0	0	0	0	0	38	0
CUCUMARIA CALCIGERA	COUNT	2	0	0	0	0	0	0	0	0
BOLTENIA OVIFERA	COUNT	0	0	0	0	0	0	0	0	0

	% OF STATIONS PRESENT
SOLARIELLA OBSCURA	43.
S.VARICOSA	17.
MARGARITES OLIVACEUS	17.
NATICA CLAUSA	19.
POLINICES PALLIDA	50.
CYLICHNA ALBA	57.
ECHINARACHNIUS PARMA	31.
DIAMPHIODIA CRATERODMETA	0.
OPHIURA SARSI	24.
CUCUMARIA CALCIGERA	12.
BOLTENIA OVIFERA	10.

APPENDIX 3.C

SOUTHEASTERN BERING SEA GRAB DATA 1975
THE BIOMASS (FORMALIN WET WEIGHT, GRAMS/M^2) OF DOMINANT INFAUNAL SPECIES COLLECTED BY VAN VEEN GRAB AT ALL STATIONS IN THE STUDY AREA

(See Fig. 2.7 for station locations)

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	1	3	4	5	6	7	8	9
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	206.547	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYLICHNA ALBA	GM/METER SQUARED	0.154	0.224	0.273	0.040	0.	0.	0.036	0.223
DIAPHIODIA CRATERODMETA	GM/METER SQUARED	9.716	0.	0.	0.	0.	0.	0.	0.
ECHINARACHNIUS PARMA	GM/METER SQUARED	0.	1.178	5.897	85.590	108.110	189.002	7.056	3.371
MARGARITES OLIVACEUS	GM/METER SQUARED	0.	0.	0.	1.455	0.	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
OPHIURA SARSI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
POLINICES PALLIDA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	1.380	0.
SOLARIELLA OBSCURA	GM/METER SQUARED	0.	0.058	0.	0.145	0.	0.219	0.724	0.756
SOLARIELLA VARICOSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.

	STATIONS	10	11	12	13	14	16	17	18
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.168	0.	0.
CYLICHNA ALBA	GM/METER SQUARED	0.172	0.194	0.062	0.451	0.	0.034	0.134	0.966
DIAPHIODIA CRATERODMETA	GM/METER SQUARED	0.	0.018	0.038	0.	0.	0.470	0.286	3.688
ECHINARACHNIUS PARMA	GM/METER SQUARED	80.730	7.834	7.876	0.075	0.	0.	0.	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.008	0.044	0.	0.	0.	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.	0.	0.450	0.	0.	0.
OPHIURA SARSI	GM/METER SQUARED	0.022	0.	0.	0.	0.	0.612	0.010	0.
POLINICES PALLIDA	GM/METER SQUARED	0.240	0.016	0.	0.	0.	0.	0.	2.560
SOLARIELLA OBSCURA	GM/METER SQUARED	0.	0.004	0.002	0.	0.018	0.	0.002	0.362
SOLARIELLA VARICOSA	GM/METER SQUARED	0.	0.	0.	0.017	0.	0.	0.	0.680

	STATIONS	19	20	22	23	24	25	27	28
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	6.892	0.	0.	0.	0.230	0.	0.	0.
CYLICHNA ALBA	GM/METER SQUARED	0.	0.360	0.226	0.098	0.	0.829	0.316	0.
DIAPHIODIA CRATERODMETA	GM/METER SQUARED	2.324	0.	0.	0.	0.115	0.	0.	0.154
ECHINARACHNIUS PARMA	GM/METER SQUARED	44.750	0.	14.185	43.408	0.	2.139	0.	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.062	0.	0.035	0.	0.020	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.097	0.	0.	0.	4.226	0.
OPHIURA SARSI	GM/METER SQUARED	28.658	0.466	0.	0.	0.033	0.	0.	49.030
POLINICES PALLIDA	GM/METER SQUARED	0.018	0.862	0.	0.	0.	1.105	0.320	0.
SOLARIELLA OBSCURA	GM/METER SQUARED	1.138	0.136	3.152	0.546	0.	0.	1.504	0.002
SOLARIELLA VARICOSA	GM/METER SQUARED	0.008	0.078	0.	0.	0.	0.	0.	0.

	STATIONS	29	30	31	35	36	37	38	39
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	631.646	0.
CYLICHNA ALBA	GM/METER SQUARED	3.532	1.180	0.057	0.018	0.090	0.	0.	0.
DIAPHIODIA CRATERODMETA	GM/METER SQUARED	13.160	0.	0.206	0.	0.454	0.340	0.	0.
ECHINARACHNIUS PARMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
OPHIURA SARSI	GM/METER SQUARED	14.172	0.	0.	0.	0.072	0.	0.	0.
POLINICES PALLIDA	GM/METER SQUARED	3.716	0.	0.	0.	0.	0.	0.	0.
SOLARIELLA OBSCURA	GM/METER SQUARED	0.052	0.070	0.	0.170	0.290	0.194	0.	0.016
SOLARIELLA VARICOSA	GM/METER SQUARED	0.028	0.232	0.004	0.	0.590	0.	0.008	0.

SOUTHEASTERN BERING SEA GRAB DATA 1975

	STATIONS	40	41	42	43	45	49	57	59
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYLICHNA ALBA	GM/METER SQUARED	0.025	0.574	0.032	0.082	0.003	0.351	0.011	2.999
DIAMPHIODIA CRATERODMETA	GM/METER SQUARED	0.	0.	0.018	0.	0.001	0.	0.	0.
ECHINARACHNIUS PARMA	GM/METER SQUARED	0.	0.326	1.252	0.	0.	0.	0.	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
OPHIURA SARSI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
POLINICES PALLIDA	GM/METER SQUARED	0.002	0.	0.054	0.	0.	0.	0.	0.
SOLARIELLA OBSCURA	GM/METER SQUARED	0.	0.	0.004	0.	0.094	0.	0.668	0.023
SOLARIELLA VARICOSA	GM/METER SQUARED	0.390	0.	0.	0.	0.177	0.012	0.025	0.

	STATIONS	60	61	62	64	65	924	935	937
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYLICHNA ALBA	GM/METER SQUARED	0.001	0.238	0.350	0.038	0.006	0.	0.	0.002
DIAMPHIODIA CRATERODMETA	GM/METER SQUARED	0.	0.	0.	3.588	0.146	0.036	0.012	0.008
ECHINARACHNIUS PARMA	GM/METER SQUARED	3.384	0.	0.	0.	0.	0.	0.	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.	0.	0.066	0.	0.	0.
OPHIURA SARSI	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
POLINICES PALLIDA	GM/METER SQUARED	0.	0.	0.	0.	0.	10.452	4.358	0.
SOLARIELLA OBSCURA	GM/METER SQUARED	0.531	0.918	0.436	0.	0.	0.	0.216	0.
SOLARIELLA VARICOSA	GM/METER SQUARED	0.	0.	0.330	0.	0.	0.	1.896	0.002

	STATIONS	942	47	55	70	71	72	73	82
BOLTENIA OVIFERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
CYLICHNA ALBA	GM/METER SQUARED	0.	0.324	0.	0.027	0.006	0.	0.	0.
DIAMPHIODIA CRATERODMETA	GM/METER SQUARED	0.	4.298	0.024	4.370	0.130	0.	0.	0.
ECHINARACHNIUS PARMA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
NATICA CLAUSA	GM/METER SQUARED	0.	0.	0.	0.	0.	0.	0.	0.
OPHIURA SARSI	GM/METER SQUARED	0.	3.236	0.038	0.	0.	0.	0.	0.
POLINICES PALLIDA	GM/METER SQUARED	8.683	0.	0.	0.	0.	0.344	0.346	0.210
SOLARIELLA OBSCURA	GM/METER SQUARED	0.	0.736	0.	0.	0.	0.	0.012	0.
SOLARIELLA VARICOSA	GM/METER SQUARED	0.	1.678	0.	0.	0.	0.	0.010	0.

	STATIONS	83
BOLTENIA OVIFERA	GM/METER SQUARED	0.
CUCUMARIA COLCIGERA	GM/METER SQUARED	0.
CYLICHNA ALBA	GM/METER SQUARED	0.366
DIAMPHIODIA CRATERODMETA	GM/METER SQUARED	0.
ECHINARACHNIUS PARMA	GM/METER SQUARED	0.
MARGARITES OLIVACEUS	GM/METER SQUARED	0.
NATICA CLAUSA	GM/METER SQUARED	0.
OPHIURA SARSI	GM/METER SQUARED	0.
POLINICES PALLIDA	GM/METER SQUARED	0.018
SOLARIELLA OBSCURA	GM/METER SQUARED	0.
SOLARIELLA VARICOSA	GM/METER SQUARED	0.

BEST DOCUMENT AVAILABLE

APPENDIX 3.D

THREE PARAMETERS AT WHICH THE MAJOR CONCENTRATIONS OF ELEVEN SPECIES OF INVERTEBRATES, TAKEN BY VAN VEEN GRAB, OCCUR IN THE SOUTHEASTERN BERING SEA

APPENDIX 3.D

SEDIMENT PARAMETERS AT WHICH THE MAJOR CONCENTRATIONS OF ELEVEN SPECIES OF INVERTEBRATES, TAKEN BY VAN VEEN GRAB, OCCUR IN THE SOUTHEASTERN BERING SEA

Species	Sediment Size	Sediment Sorting	% Mud (range)	Depth	Text Figs.	Text Tables
Solariella obscura	medium to fine sand (59%)*	very well to moderately well sorted (52%)	0-70	<25- 75 m (82%)	3.1	3.II-3.V
Solariella varicosa	fine sand to medium silt (64%)	poorly sorted (67%)	0-70	50-100 m (75%)	3.1	3.II-3.V
Margarites olivaceus	medium to fine sand (80%)	poorly sorted (79%)	0-40	25- 50 m (66%)	3.2	3.II-3.V
Natica clausa	medium sand to coarse silt (63%)	poorly to very poorly sorted (556%)	0-50	100-175 m (56%)	3.3	3.II-3.V
Polinices pallida	fine sand to coarse silt (72%)	very well to moderately sorted (52%)	0-70	50- 75 m (62%)	3.3	3.II-3.V
Cylichna alba	medium sand to medium silt (98%)	moderately to poorly sorted (62%)	0-70	25-100 m (72%)	3.4	3.II-3.V
Echinarachnius parma	medium to fine sand (69%)	well to moderately sorted (72%)	0-40	<25- 75 m (99%)	3.5	3.II-3.V
Diamphiodia craterodmeta	fine sand to coarse silt (86%)	poorly sorted (88%)	0-70	75-100 m (79%)	3.6	3.II-3.V
Ophiura sarsi	fine to very fine sand (82%)	poorly sorted (97%)	0-70	50-100 m (83%)	3.7	3.II-3.V
Cucumaria calcigera	very fine sand to coarse silt (98%)	poorly sorted (99%)	0-60	50- 75 m (98%)	3.8	3.II-3.V
Boltenia ovifera	coarse to medium silt (100%)	poorly sorted (100%)	0-50	50- 75 m (100%)	3.9	3.II-3.V

---

*The percentages in parentheses throughout the table refer to the major concentration of the particular species at a given parameter.

SECTION 4

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES INCIDENTLY COLLECTED BY CLAM DREDGE ON THE F/V *SMARAGD*

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study were to (1) examine the distribution of the pinkneck clam, *Spisula polynyma*, (2) examine the distribution of selected common marine invertebrates incidently collected by clam dredge, and (3) relate the distribution of selected commor species to sediment size.

Invertebrates were obtained in 170 tows from 73 stations. Many species were collected with *Spisula polynyma*. Twelve invertebrate species were common in regions of high *S. polynyma* densities (Stations H-15-2, F-13-2 and Dublin Bay) from Ugashik Bay to Port Moller: *Nephtys caeca*, *Nicomache* sp., *Sabella media*, *Astarte rollandi*, *Cyclocardia crebricostata*, *Serripes groenlandicus*, *S. laperousii*, *Macoma middendorffi*, *Tellina lutea*, *Echinarachnius parma*, *Boltenia ovifera* and *Styela rustica macrenteron*.

No apparent difference in species numbers and biomass were noted for the cobble and boulders underlying the sand-gravel substrate located in the outwash areas of the bays as compared to the coarse-medium sands located between the latter areas and the mid-shelf.

Polychaetes collected were associated with coarse-medium sands at 18-47 m, while pelecypods occurred in coarse-medium sands at 18-55 m depths. Gastropods collected were associated with medium-fine sands at 18-47 m, while echinoderms occurred in coarse-medium sand at 18-47 m depths. Tunicates were associated with coarse-medium sands at 18-47 m depths.

See Section 1 for comments on Implications with Respect to Oil and Gas Development.

II. INTRODUCTION

Recent OCSEAP trawl studies in the southeastern Bering Sea (Feder and Jewett, 1978; Feder *et al.*, 1977, 1978a) have been restricted to deeper depths due to vessel size; thus, inshore subtidal invertebrate distribution and abundance data were limited. A hydraulic clam dredge utilized in a joint exploratory clam survey in 1977 for the large clam, *Spisula*

BEST DOCUMENT AVAILABLE

polynyma, made it possible to obtain information from depths of 16 to 55 m (Hughes, 1977; Ritchie, 1977).

This section considers the invertebrate species, collected with a hydraulic clam dredge, that were taken incidently to *S. polynyma* as part of an assessment study by the National Marine Fisheries Service (NMFS).

III. CURRENT STATE OF KNOWLEDGE

The pinkneck, *Spisula polynyma*, is a large bivalve found in intertidal and subtidal Alaskan waters. The extent of this resource, until recently, was relatively unknown; however, a cooperative survey by the National Marine Fisheries Service, University of Alaska, Alaska Department of Fish and Game and private interests located populations with commercial potential in the eastern Bering Sea (Hughes, 1977; Hughes *et al.*, 1977; Stoker, 1977).

Previous literature on *S. polynyma* is restricted to a geographic study by Chamberlin and Stearns (1963) and a report on growth and size-weight relationships of intertidal pinknecks in Prince William Sound (Feder *et al.*, 1976c). Growth data are also available for subtidal Cook Inlet pinkneck clams (Feder *et al.*, 1978a). A preliminary study on the biology of subtidal Bering Sea pinkneck clams is included in Feder *et al.* (1978b). An extensive literature review pertaining to a restricted portion of the clam survey area examined by Hughes (1977) and Hughes *et al.* (1977), USGS Block 60, is found in Kauwling and Bakus (1979). The latter report also includes the results of a study designed to determine the effects of hydraulic clam harvesting in the southeastern Bering Sea.

IV. STUDY AREA

The survey was carried out at depths of 16-55 m in bays of Unalaska Island and along the Bering Sea side of the Alaska Peninsula between Urilia Bay on Unimak Island and Port Moller. Details of the study area are found in Hughes *et al.* (1977) and Hughes (1977). See Table 4.I for station data and Figure 4.1 for trawl survey pattern.

Volcanic disturbances and sediment transport into the bays along the Alaska Peninsula have deposited a sediment-ash layer over cobbles and

TABLE 4.I

STATIONS OCCUPIED IN THE BERING SEA ON THE *SPISULA POLYNYMA* SURVEY BY THE F/V *SMARAGD* AND THE NUMBER OF CLAMS COLLECTED BY STATION

Station No.	Tow No.	Latitude	Longitude	Depth (m)	No. of *Spisula polynyma*
I111	2	57°48.0'	161°13.0'	43.7	50
I111	3	57°48.0'	161°15.0'	41.9	1
I111	4	57°48.0'	161°15.0'	43.7	12
I111	5	57°48.0'	161°16.0'	43.7	-*
I111	6	57°48.0'	161°16.0'	41.7	13
I114	7	57°45.0'	161°35.0'	45.5	2
I101	8	57°44.0'	161°53.0'	41.9	1
I104	9	57°44.0'	162°09.0'	40.0	1
I091	10	57°41.0'	162°20.0'	40.0	5
J091	11	58°01.0'	162°30.0'	36.4	-
K092	12	58°11.0'	162°34.0'	30.9	-
J104	13	58°07.0'	162°13.0'	32.8	2
J101	14	58°07.0'	161°53.0'	43.7	-
J114	15	58°06.0'	161°37.0'	34.6	-
J111	16	58°02.0'	161°12.0'	38.2	6
J124	17	58.01.0'	160°55.0'	36.4	-
J123	18	57°53.0'	160°54.0'	41.9	-
H152	19	57°13.0'	158°37.0'	25.5	81
G151	20	57°06.0'	158°54.0'	26.4	76
G154	21	57°01.0'	159°06.0'	29.1	-
G153	22	56°57.0'	159°12.0'	25.5	-
G153	23	56°52.0'	159°13.0'	23.7	-
F141	24	56°42.0'	159°34.0'	25.5	70
F141	25	56°42.0'	159°33.0'	21.8	-
F143	26	56°40.0'	159°41.0'	25.5	14
F132	27	56°36.0'	159°55.0'	23.6	284
E131	28	56°32.0'	160°16.0'	29.1	73
E134	29	56°25.0'	160°27.0'	29.1	23
E133	30	56°12.0'	160°38.0'	21.5	-
E122	31	56°12.0'	160°45.0'	25.5	-
D121	32	56°06.0'	160°42.0'	14.6	-
D121	33	56°04.0'	160°37.0'	25.5	-
E133	34	56°08.0'	160°32.0'	16.4	-
E131	35	56°28.0'	160°11.0'	18.2	41
F132	36	56°36.0'	159°55.0'	21.8	110
F132	37	56°36.0'	159°56.0'	27.3	172
F131	38	56°38.0'	159°57.0'	36.4	82
F144	39	56°43.0'	159°41.0'	30.0	208
G142	40	56°50.0'	159°39.0'	40.0	40
G142	41	56°52.0'	159°29.0'	36.4	12
G141	42	56°59.0'	159°22.0'	36.4	5
H153	43	57°09.0'	159°04.0'	38.2	1

TABLE 4.I

CONTINUED

Station No.	Tow No.	Latitude	Longitude	Depth (m)	No. of *Spisula polynyma*
H151	44	57°19.0'	158°43.0'	36.4	32
I164	45	57°24.0'	158°34.0'	32.8	86
I163	46	57°34.0'	158°27.0'	34.6	4
I162	47	57°36.0'	158°19.0'	29.1	11
I164	48	57°41.0'	158°23.0'	30.9	9
I161	49	57°46.0'	158°19.0'	32.8	3
I161	50	57°58.0'	158°51.0'	32.8	2
J142	51	57°53.0'	159°24.0'	34.6	-
J141	52	57°53.0'	159°30.0'	34.6	1
J144	53	57°52.0'	159°36.0'	36.4	-
J143	54	57°52.0'	159°43.0'	38.2	5
I141	55	57°43.0'	159°30.0'	41.9	1
I143	56	57°32.0'	159°40.0'	47.3	28
I142	57	57°28.0'	159°30.0'	52.8	5
H141	58	57°26.0'	159°28.0'	51.0	26
H143	59	57°23.0'	159°40.0'	51.0	4
H121	60	57°25.0'	160°41.0'	56.4	-
H124	61	57°26.0'	160°52.0'	58.2	-
I123	62	57°31.0'	161°06.0'	52.8	2
I112	63	57°34.0'	161°11.0'	51.0	-
H111	64	57°28.0'	161°21.0'	49.1	4
H111	65	57°26.0'	161°23.0'	51.0	10
H112	66	57°18.0'	161°23.0'	54.6	-
H113	67	57°15.0'	161°37.0'	51.0	-
H102	68	57°14.0'	161°53.0'	43.7	24
H103	69	57°13.0'	162°12.0'	47.3	7
H092	70	57°13.0'	162°25.0'	47.3	2
H093	71	57°16.0'	162°45.0'	47.3	-
H094	72	57°23.0'	162°47.0'	43.7	-
I093	73	57°30.0'	162°55.0'	43.7	-
I081	74	57°41.0'	163°00.0'	41.9	1
J083	75	57°50.0'	163°27.0'	41.9	1
L053	76	58°30.0'	165°16.0'	38.2	1
L054	77	58°45.0'	165°18.0'	27.3	1
OBB1	78	58°56.0'	166°38.0'	27.3	3
OBB2	79	58°56.0'	166°38.0'	40.0	-
OKB1	80	54°00.0'	166°21.0'	25.5	-
OKB2	81	58°59.0'	166°22.0'	32.8	29
OKB3	82	58°59.0'	166°22.0'	34.6	17
OKB4	83	58°59.0'	166°22.0'	32.8	-
ODB1	84	54°43.0'	164°44.0'	32.8	11
ODB2	85	54°42.0'	164°43.0'	12.7	-
ODB3	86	54°42.0'	164°44.0'	18.2	6

TABLE 4.I

CONTINUED

Station No.	Tow No.	Latitude	Longitude	Depth (m)	No. of *Spisula polynyma*
ODB4	87	54°42.0'	164°45.0'	25.5	81
ODB5	88	54°43.0'	164°47.0'	38.2	29
ODB6	89	54°44.0'	164°48.0'	43.7	-
ODB7	90	54°42.0'	164°45.0'	27.3	90
ODB8	91	54°43.0'	164°44.0'	30.9	64
ODB9	92	54°43.0'	164°43.0'	27.3	30
DB10	93	54°50.0'	164°38.0'	27.3	-
OUB1	94	54°56.0'	164°17.0'	16.4	-
OUB2	95	54°56.0'	164°16.0'	16.4	-
OUB3	96	54°56.0'	164°16.0'	20.0	-
OUB4	97	54°57.0'	164°18.0'	25.5	-
ONC1	98	55°08.0'	163°47.0'	29.1	-
OSL1	99	55°09.0'	163°46.0'	34.6	-
OCK1	100	55°08.0'	163°24.0'	16.4	-
C093	101	55°29.0'	162°52.0'	30.9	1
C093	102	55°32.0'	162°53.0'	36.4	2
C092	103	55°37.0'	162°44.0'	36.4	1
C102	104	55°44.0'	162°21.0'	32.8	-
F132	105	56°33.0'	160°11.0'	29.1	92
F132	106	56°32.0'	160°14.0'	30.9	98
F137	107	56°31.0'	160°14.0'	30.9	230
F132	108	56°31.0'	160°12.0'	30.9	435
F132	109	56°32.0'	160°11.0'	30.9	108
F132	110	56°32.0'	160°09.0'	27.3	39
F132	111	56°34.0'	160°07.0'	27.3	176
E132	112	56°34.0'	160°06.0'	29.1	214
F132	113	56°35.0'	160°05.0'	29.1	84
F132	114	56°36.0'	160°02.0'	29.1	6
F132	115	56°36.0'	159°59.0'	31.9	288
F132	116	56°36.0'	159°57.0'	29.1	130
F132	117	56°36.0'	159°53.0'	29.1	18
F132	118	56°37.0'	159°48.0'	25.5	46
F132	119	56°38.0'	159°46.0'	29.1	102
F144	120	56°39.0'	159°48.0'	30.9	43
F144	121	56°39.0'	159°48.0'	30.9	189
F144	122	56°40.0'	159°47.0'	30.9	62
F144	123	56°40.0'	159°47.0'	32.8	112
F144	124	56°41.0'	159°47.0'	32.8	212
F144	125	56°43.0'	159°45.0'	32.8	62
F144	126	56°43.0'	159°42.0'	32.8	60
F132	127	56°36.0'	159°58.0'	30.9	30
F144	128	56°46.0'	159°49.0'	40.0	16
F144	129	56°44.0'	159°46.0'	34.6	30
F144	130	56°43.0'	159°41.0'	29.1	88

TABLE 4.I

CONTINUED

Station No.	Tow No.	Latitude	Longitude	Depth (m)	No. of *Spisula polynyma*
F144	131	56°42.0'	159°40.0'	30.9	304
F144	132	56°44.0'	159°39.0'	29.1	-
F144	133	56°44.0'	159°38.0'	29.1	158
F144	134	56°49.0'	159°33.0'	29.1	-
G142	135	56°50.0'	159°26.0'	30.9	-
G142	136	56°51.0'	159°28.0'	30.9	-
F131	137	56°30.0'	160°14.0'	25.5	73
E131	138	56°29.0'	160°16.0'	29.1	195
E131	139	56°30.0'	160°18.0'	27.3	159
E131	140	56°30.0'	160°19.0'	29.1	392
E131	141	56°31.0'	160°19.0'	29.1	147
E131	142	56°31.0'	160°19.0'	30.9	390
E131	143	56°30.0'	160°20.0'	30.9	-
E131	144	56°30.0'	160°22.0'	32.8	144
E134	145	56°30.0'	160°20.0'	30.9	288
E134	146	56°30.0'	160°19.0'	29.1	173
E134	147	56°29.0'	160°19.0'	29.1	160
E134	148	56°29.0'	160°20.0'	30.9	152
E134	149	56°29.0'	160°21.0'	30.9	103
E134	150	56°28.0'	160°22.0'	30.9	174
E134	151	56°28.0'	160°21.0'	25.5	187
E134	152	56°27.0'	160°21.0'	25.5	194
E134	153	56°27.0'	160°24.0'	29.1	87
E134	154	56°26.0'	160°25.0'	27.3	181
E134	155	56°27.0'	160°25.0'	29.1	158
E134	156	56°26.0'	160°25.0'	27.3	78
E134	157	56°26.0'	160°27.0'	30.9	-
E134	158	56°26.0'	160°26.0'	30.9	158
E134	159	56°27.0'	160°21.0'	23.7	233
E134	160	56°28.0'	160°22.0'	27.3	343
E132	161	56°28.0'	160°23.0'	29.1	195
F132	162	56°37.0'	159°54.0'	30.9	174
F143	163	56°38.0'	159°53.0'	30.9	449
F143	164	56°37.0'	159°54.0'	30.9	13
F144	165	56°38.0'	159°53.0'	30.9	2
F144	166	56°38.0'	159°53.0'	30.9	348
F144	167	56°38.0'	159°53.0'	30.9	238
F144	168	56°38.0'	159°53.0'	30.9	-
F144	169	56°38.0'	159°52.0'	30.9	405
F144	170	56°40.0'	159°52.0'	38.2	189
F144	171	56°42.0'	159°37.0'	29.1	55
F144	172	56°43.0'	159°36.0'	29.1	32
F144	173	56°45.0'	159°37.0'	32.8	23
F141	174	56°47.0'	159°31.0'	30.9	-

TABLE 4.I

CONTINUED

Station No.	Tow No.	Latitude	Longitude	Depth (m)	No. of *Spisula polynyma*
G151	175	57°05.0'	158°54.0'	25.5	25
G151	176	57°06.0'	158°53.0'	27.3	159
G151	177	57°07.0'	158°52.0'	27.3	574
G151	178	57°06.0'	158°53.0'	25.5	212
G151	179	57°07.0'	158°52.0'	27.3	-
H152	180	57°09.0'	158°51.0'	29.1	25
H152	181	57°09.0'	158°51.0'	29.1	12
H152	182	57°10.0'	158°51.0'	30.9	145
H152	183	57°10.0'	158°50.0'	29.1	211
H152	184	57°09.0'	158°50.0'	27.3	236
H152	185	57°10.0'	158°49.0'	29.1	75
H152	186	57°10.0'	158°49.0'	30.9	95
H152	187	57°11.0'	158°43.0'	29.1	5
H152	188	57°12.0'	158°38.0'	27.3	-
H163	189	57°13.0'	158°35.0'	25.5	-
H152	190	57°13.0'	158°40.0'	32.8	1
H152	191	57°16.0'	158°42.0'	36.4	12
H152	192	57°18.0'	158°45.0'	38.2	8
H152	193	57°20.0'	158°47.0'	38.2	2
H151	194	57°23.0'	158°43.0'	38.2	67
H151	195	57°23.0'	158°40.0'	36.4	3
F144	196	56°38.0'	159°52.0'	30.9	736
F144	197	56°38.0'	159°53.0'	30.9	803
F144	198	56°38.0'	159°52.0'	29.1	154
F144	199	56°38.0'	159°53.0'	30.9	128
F144	200	56°38.0'	159°53.0'	30.9	726
F144	201	56°37.0'	159°52.0'	29.1	400
F144	202	56°37.0'	159°51.0'	27.3	400
H164	203	57°18.0'	158°36.0'	32.8	144
H163	204	57°17.0'	158°34.0'	30.9	-
H164	205	57°21.0'	158°30.0'	30.9	446
H164	206	57°21.0'	158°30.0'	29.1	379
H164	207	57°21.0'	158°30.0'	29.1	421
H164	208	57°22.0'	158°28.0'	27.3	234
H164	209	57°23.0'	158°32.0'	29.1	424
H164	210	57°25.0'	158°33.0'	30.9	291
H164	211	57°25.0'	158°33.0'	34.6	149
H164	212	57°26.0'	158°33.0'	30.9	84
H164	213	57°28.0'	158°33.0'	32.8	68
H164	214	57°27.0'	158°29.0'	29.1	206
H164	215	57°25.0'	158°27.0'	27.3	356
H164	216	57°25.0'	158°26.0'	29.1	177
H164	217	57°23.0'	158°24.0'	27.3	223

TABLE 4.I

CONTINUED

Station No.	Tow No.	Latitude	Longitude	Depth (m)	No. of *Spisula polynyma*
H164	218	57°24.0'	158°26.0'	29.1	248
H164	219	57°22.0'	158°30.0'	30.9	289
H164	220	57°21.0'	158°30.0'	29.1	620
H164	221	57°21.0'	158°30.0'	29.1	325
H164	222	57°21.0'	158°30.0'	29.1	467
H164	223	57°21.0'	158°30.0'	29.1	317
H164	224	57°21.0'	158°30.0'	27.3	408
H164	225	27°21.0'	158°30.0'	27.3	537
G151	226	57°07.0'	158°52.0'	30.9	374
G151	227	57°07.0'	158°52.0'	25.5	621
G151	228	57°07.0'	158°52.0'	25.5	610
G151	229	57°07.0'	158°33.0'	29.1	351
G151	230	57°07.0'	158°52.0'	27.3	60

---

*-indicates no *Spisula polynyma* present in clam dredge.

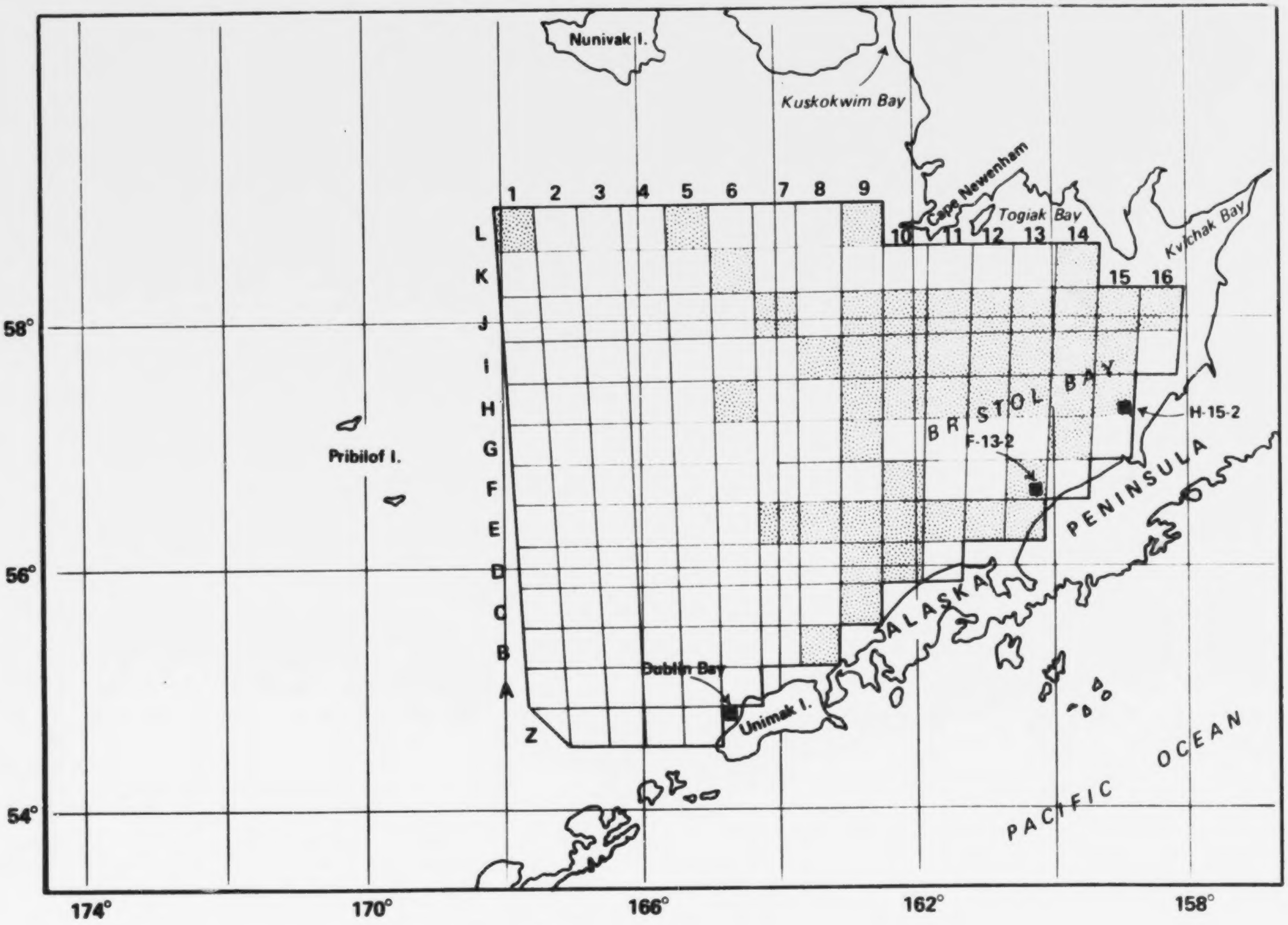

Nunivak I.
Kuskokwim Bay
Cape Newenham
Togiak Bay
Kvichak Bay
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
L
K
J
I
H
G
F
E
D
C
B
A
Z
58°
56°
54°
BRISTOL BAY
H-15-2
F-13-2
Pribilof I.
PENINSULA
ALASKA
Dublin Bay
Unimak I.
PACIFIC OCEAN
174°
170°
166°
162°
158°

Figure 4.1. National Marine Fisheries Service Bering Sea trawl survey pattern shows locations (shaded) of 400 square mile areas (blocks) where pinkneck clams (*Spisula polynyma*) were obtained in otter trawl surveys.

BEST DOCUMENT AVAILABLE

boulders there, often forming a plume approximately 6-8 km in radius at the bay mouths. Patchy occurrences of this ash often occur between these plumes. At several stations between Port Moller and Port Heiden in approximately 30-40 m depths, volcanic sand formed a compact layer conforming to the underlying rock material. Reduced mud occurred at several stations midway between Port Moller and Port Heiden, interspersed between the sandy stations. The odor of sulfide was often noted when volcanic material was crumbled.

V. METHODS

Invertebrate specimens were collected in July and August 1977 from the F/V *Smaragd* with a modified East Coast hydraulic clam dredge, the diameter of the rings in the retaining steel mesh bag were 75 mm. The dredge was set and retrieved from the starboard side of the vessel with the trawl winch, towed with a 3-inch diameter polypropylene line, and lifted on and off the vessel with two booms.

All specimens, with the exception of *Spisula polynyma* collected by the National Marine Fisheries Service, were enumerated, weighed, identified, and fixed in 10% buffered formalin.

The survey was conducted in two parts. The first part was designed to cover a wide geographic and bathymetric zone in areas where surf clams had been obtained in NMFS trawl surveys from 1969-1976 (Fig. 4.1). The second part was designed for intensive coverage of regions (blocks) where clams were located during part one. This was accomplished by numerous tows of 10-15 minute duration in selected blocks (see Hughes *et al.*, 1977 for further details on sampling).

Sediment data were obtained from Hoskin (1975), Sharma (1972), and field observations. Also, see sediment summarizations and discussions in Sections 2 and 3.

The distribution of 17 common species of invertebrates are examined in relation to sediment parameters.

VI. RESULTS

Invertebrates were obtained in 170 dredge samples taken from 73 stations. Many of the invertebrates collected were seriously damaged by the dredging process, and could only be determined to higher taxonomic categories.

Invertebrates from 9 phyla, approximately 51 families, and approximately 92 species were taken. Five species of fishes in three families were also obtained (Tables 4.II-4.V). Five invertebrate phyla/groups - Mollusca, Echinodermata, Annelida, Arthropoda (Crustacea), and Chordata (Urochordata/Tunicata) - dominated by number; groups are listed in decreasing order of dominance (Table 4.III). Five invertebrate groups - Mollusca, Echinodermata, Arthropoda (Crustacea), Chordata (Urochordata), and Cnidaria (sea anemones) - dominated by weight; groups are listed in decreasing order of dominance (Table 4.III).

Approximately seven invertebrate species - *Spisula polynuma, Tellina lutea, Asterias amurensis, Nicomache* spp., *Sabella media, Balanus* spp. and *Echinarachnius parma* - dominated by number; groups are listed in decreasing order of dominance (Table 4.V). Approximately six invertebrate species - *Spisula polynyma, Asterias amurensis, Tellina lutea, Paralithodes camtschatica, Boltenia ovifera,* and *Cucumaria* spp. - dominated by weight; groups are listed in decreasing order of dominance (Table 4.V).

Eleven invertebrate species - *Spisula polynyma* (178), *Asterias amurensis* (130), *Tellina lutea* (109), *Serripes groenlandicus* (51), *Siliqua alta* (47), *Pagurus ochotensis* (46), *Serripes laperousii* (44), *Paralithodes camtschatica* (42), *Echinarachnius parma* (38), *Macoma middendorffi* (34) and *Telmessus cheiragonus* (34) - dominated by number of station occurrences; species above are listed in decreasing order of occurrence with the number of occurrences in parentheses (Table 4.VI).

Many of the above species were commonly associated with the pinkneck clam, *Spisula polynyma*. Throughout the areas of high *S. polynyma* densities (Stations H-15-2, F-13-2 and Dublin Bay) (Fig. 4.1) from Ugashik Bay to Port Moller, the following species occurred: *Nephtys caeca, Nicomache* sp., *Sabella media, Astarte rollandi, Cyclocardia crebricostata, Serripes*

TABLE 4.II

A LIST OF SPECIES TAKEN BY HYDRAULIC DREDGE BY THE F/V *SMARAGD* IN THE SOUTHEASTERN BERING SEA

- Phylum Porifera

- Phylum Cnidaria
  - Class Hydrozoa
  - Class Anthozoa
    - Family Nephtheidae
      - *Eunephthys rubiformis*
    - Family Actiniidae

- Phylum Rhynchocoela

- Phylum Annelida
  - Class Polychaeta
    - Family Polynoidae
    - Family Nereidae
      - *Nephtys caeca*
    - Family Chaetopteridae
      - *Chaetopterus variopedatus*
    - Family Opheliidae
      - *Ophelia limacina*
      - *Travisia forbesii*
    - Family Maldanidae
      - *Nicomache* spp.
    - Family Sabellidae
      - *Chone cincta*
      - *Sabella media*
  - Class Hirudinea
    - *Notostomobdella* spp.

- Phylum Mollusca
  - Class Pelecypoda
    - Family Nuculanistae
      - *Yoldia* spp.
      - *Yoldia scissurata*
    - Family Mytilidae
      - *Mytilus edulis*
      - *Musculus niger*
      - *Musculus discors*
      - *Modiolus modiolus*
    - Family Pectinidae
      - *Pecten caurinus*
    - Family Anomiidae
      - *Pododesmus machrochisma*
    - Family Astartidae
      - *Astarte alaskensis*
      - *Astarte montaqui*
      - *Astarte rollandi*
    - Family Carditidae
      - *Cyclocardia crebricostata*
    - Family Ungulinidae
      - *Diplodonta aleutica*
    - Family Cardiidae
      - *Clinocardium ciliatum*
      - *Clinocardium nuttallii*
      - *Clinocardium californiense*
      - *Serripes groenlandicus*
      - *Serripes laperousii*
    - Family Mactridae
      - *Spisula polynyma*
    - Family Tellinidae
      - *Macoma* spp.
      - *Macoma calcarea*
      - *Macoma middendorffi*
      - *Tellina lutea alternidentata*
    - Family Solenidae
      - *Siliqua alta*
    - Family Myidae
      - *Mya truncata*
      - *Mya elegans*
    - Family Hiatellidae
      - *Hiatella arctica*
      - *Panope generosa*
    - Family Throciidae
      - *Thracia myopsis*
  - Class Gastropoda
    - Family Trochidae
      - *Solariella obscura*
    - Family Turritellidae
      - *Tochyrynchus erosus*
    - Family Naticidae
      - *Amauropsis purpurea*
      - *Natica clausa*
    - Family Velutinidae
      - *Velutina undata*
    - Family Buccinidae
      - *Buccinum glaciale*
    - Family Neptuneidae
      - *Beringius beringi*
      - *Neptunea lyrata*
      - *Neptunea ventricosa*
      - *Neptunea heros*

- Phylum Arthropoda
  - Class Pycnogonida

TABLE 4.II

CONTINUED

- Class Crustacea
  - Family Balanidae
    - *Balanus* spp.
    - *Balanus balanus*
    - *Balanus nubilis*
  - Order Isopoda
    - Family Idoteidae
      - *Synidotea nodulosa*
  - Order Amphipoda
    - Family Lyiannassidae
      - *Anonyx* spp.
    - Family Caprellidae
  - Order Decapoda
    - Family Crangonidae
      - *Crangon dalli*
      - *Argis crassa*
    - Family Paguridae
      - *Pagurus ochotensis*
      - *Pagurus capillatus*
      - *Pagurus trigonocheirus*
      - *Labidochirus splendescens*
    - Family Lithodidae
      - *Paralithodes camtschatica*
    - Family Majiidae
      - *Oregonia gracilis*
      - *Hyas lyratus*
      - *Hyas coarctatus alutoceus*
      - *Chionoecetes opilio*
      - *Chionoecetes bairdi*
    - Family Atelecyclidae
      - *Telmessus cheiragonus*
      - *Erimacrus isenbeckii*

- Phylum Sipunculida

- Phylum Echiurida
  - Class Echiuridae
    - Family Echiuridae
      - *Echiurus echiurus alaskanus*

- Phylum Ectoprocta
  - Class Cheilostomata
    - Family Flustridae
    - Family Bicelliariellidae
      - *Dendrobeania* spp.
  - Class Ctenostomata
    - Family Alcyonidiidae
      - *Alcyonidium* spp.

- Phylum Echinodermata
  - Class Asteroidea
    - Family Echinasteridae
      - *Henricia* sp.
    - Family Asteridae
      - *Asterias amurensis*
      - *Evasterias echinosoma*
      - *Evasterias troschelii*
      - *Leptasterias* spp.
  - Class Echinoidea
    - Family Echinarachniidae
      - *Echinarachnius parma*
    - Family Strongylocentrotidae
      - *Strongylocentrotus droebachiensis*
  - Class Ophiuroidea
    - Family Amphiuridae
      - *Diamphiodia craterodmeta*
    - Family Gorgonocephalidae
      - *Gorgonocephalus caryi*
    - Family Ophiuridae
      - *Stegophiura nodosa*
  - Class Holothuroidea
    - Family Cucumariidae
      - *Cucumaria* spp.
      - *Cucumaria calcigera*

- Phylum Urochordata
  - Class Stolidobranchia
    - Family Rhodosomatidae
      - *Chelyosoma* spp.
    - Family Styelidae
      - *Styela rustica macrenteron*
    - Family Pyuridae
      - *Boltenia ovifera*

- Phylum Chordata
  - Family Cottidae
    - *Gymnocanthus* spp.
    - *Myoxocephalus* spp.
  - Family Ammodytidae
    - *Ammodytes hexapterus*
  - Family Pleuronectidae
    - *Hippoglossoides robustus*
    - *Lepidopsetta bilineata*

TABLE 4.III

PERCENTAGE COMPOSITION BY WEIGHT - ALL PHYLA

Taxon Name	Count	% Count	Weight[1]	% Weight	All Sta g/m^2	% Biomass
Porifera	0.	0.	11977.00	0.1316	0.02324	0.13
Cnidaria	89.00	0.1094	36081.00	0.3964	0.07002	0.40
Annelida	10874.00	13.3724	1935.00	0.0213	0.00376	0.02
Mollusca	46872.00	61.3303	6263072.00	68.8123	12.15422	68.81
Crustacea	3423.00	4.2095	180711.00	1.9855	0.35069	1.99
Echiuroidea	67.00	0.0824	904.00	0.0099	0.00175	0.01
Ectoprocta	1.00	0.0012	91.00	0.0010	0.00018	0.00
Echinodermata	16444.00	20.2221	2520933.00	27.6974	4.89217	27.70
Urochordata	494.00	0.6075	81508.00	0.8955	0.15818	0.90
Teleostei	17.00	0.0209	4468.00	0.0491	0.00867	0.05
TOTAL			9101680.00		17.6629	

[1] Weight is reported in grams.

BEST DOCUMENT AVAILABLE

532

TABLE 4.IV

COMPOSITION OF ALL PHYLA BY FAMILY

Taxon Name	Count	% Count	Weight[1]	% Weight	All Sta g/m^2	% Biomass
Porifera	0.	0.	11977.00	0.1316	0.02324	0.13
Alcyonacea Nephtheidae	0.	0.	130.00	0.0014	0.00025	0.00
Nephtyidae	410.00	0.5042	1251.00	0.0138	0.00243	0.01
Chaetopteridae	151.00	0.1857	5.00	0.0001	0.00001	0.00
Opheliidae	74.00	0.0910	85.00	0.0009	0.00016	0.00
Maldanidae	5462.00	6.7169	2.00	0.0000	0.00000	0.00
Sabellidae	4763.00	5.8573	527.00	0.0058	0.00102	0.01
Piscicolidae	3.00	0.0037	3.00	0.0000	0.00001	0.00
Monoplacophora	39.00	0.0480	11350.00	0.1252	0.02203	0.13
Nuculanidae	2.00	0.0025	2.00	0.0000	0.00000	0.00
Mytilidae	43.00	0.0529	61.00	0.0007	0.00012	0.00
Pectinidae	1.00	0.0012	454.00	0.0050	0.00088	0.01
Anomiidae	1.00	0.0012	5.00	0.0001	0.00001	0.00
Astartidae	140.00	0.1722	765.00	0.0084	0.00148	0.01
Carditidae	378.00	0.4648	927.00	0.0102	0.00180	0.01
Ungulinidae	1.00	0.0012	2.00	0.0000	0.00000	0.00
Cardiidae	800.00	0.9838	183413.00	2.0232	0.35593	2.02
Mactridae	25514.00	31.3760	5416400.00	59.7469	10.51116	59.75
Tellinidae	22523.00	27.6978	614334.00	6.7766	1.19219	6.78
Solenidae	141.00	0.1734	11026.00	0.1216	0.02140	0.12
Myidae	35.00	0.0430	4063.00	0.0448	0.00788	0.04
Hiatellidae	72.00	0.0885	78.00	0.0009	0.00015	0.00
Thraciidae	1.00	0.0012	8.00	0.0001	0.00002	0.00
Trochidae	1.00	0.0012	1.00	0.0000	0.00000	0.00
Turritellidae	1.00	0.0012	1.00	0.0000	0.00000	0.00
Naticidae	5.00	0.0061	14.00	0.0002	0.00003	0.00
Velutinidae	1.00	0.0012	1.00	0.0000	0.00000	0.00
Buccinidae	1.00	0.0012	4.00	0.0000	0.00001	0.00

TABLE 4.IV

CONTINUED

Taxon Name	Count	% Count	Weight	% Weight	All Sta g/m^2	% Biomass
Neptuneidae	171.00	0.2103	20159.00	0.2224	0.03912	0.22
Balanidae	2239.00	2.7534	7089.00	0.0782	0.01376	0.08
Idoteidae	1.00	0.0012	1.00	0.0000	0.00000	0.00
Lysianassidae	6.00	0.0074	7.00	0.0001	0.00001	0.00
Crangonidae	4.00	0.0049	9.00	0.0001	0.00002	0.00
Paguridae	139.00	0.1709	2975.00	0.0328	0.00577	0.03
Lithodidae	131.00	0.1611	130869.00	1.4436	0.25397	1.44
Majiidae	138.00	0.1697	15118.00	0.1668	0.02934	0.17
Atelecyclidae	128.00	0.1574	24588.00	0.2712	0.04772	0.27
Echiuridae	67.00	0.0824	904.00	0.0100	0.00175	0.01
Bicellariellidae	0.	0.	5.00	0.0001	0.00001	0.00
Alcyonidiidae	1.00	0.0012	67.00	0.0007	0.00013	0.00
Echinasteridae	1.00	0.0012	20.00	0.0002	0.00004	0.00
Asteridae	14512.00	17.8462	2468207.00	27.2262	4.78984	27.23
Echinarachniidae	1769.00	2.1754	3095.00	0.0341	0.00601	0.03
Strongylocentrotidae	13.00	0.0160	242.00	0.0027	0.00047	0.00
Amphiuridae	2.00	0.0025	1.00	0.0000	0.00000	0.00
Gorgonocephalidae	43.00	0.0529	4456.00	0.0492	0.00865	0.05
Ophiuridae	6.00	0.0074	6.00	0.0001	0.00001	0.00
Cucumariidae	98.00	0.1205	44906.00	0.4953	0.08715	0.50
Rhodosomatidae	2.00	0.0025	70.00	0.0008	0.00014	0.00
Styelidae	227.00	0.2792	3160.00	0.0349	0.00613	0.03
Pyuridae	263.00	0.3234	78258.00	0.8632	0.15187	0.86
Cottidae	3.00	0.0037	614.00	0.0068	0.00119	0.01
Ammodytidae	2.00	0.0025	20.00	0.0002	0.00004	0.00
Pleuronectidae	12.00	0.0148	3834.00	0.0423	0.00744	0.04

[1] Weight is reported in grams.

TABLE 4.V

COMPOSITION OF ALL PHYLA BY SPECIES

Taxon Name	Count	% Count	Weight[1]	% Weight	Occ Sta g/m^2	All Sta g/m^2	Biom %	Phyl C %	Phyl W %
Porifera	0.	0.	11977.00	0.13	0.4262	0.02324	0.13	0.	100.00
Hydrozoa	0.	0.	44.00	0.00	0.0054	0.00009	0.00	0.	0.12
Scyphozoa	26.0	0.0	34962.00	0.39	2.1318	0.06785	0.39	29.21	96.90
Eunephthya rubiformis	0.	0.	130.00	0.00	0.0079	0.00025	0.00	0.	0.36
Actinidae	63.0	0.1	945.00	0.01	0.0290	0.00183	0.01	70.79	2.62
Turbellaria	1.0	0.0	1.00	0.00	0.0004	0.00000	0.00	100.00	100.00
Rhynchocoela	29.0	0.0	82.00	0.00	0.0062	0.00016	0.00	100.00	100.00
Polychaeta	5.0	0.0	4.00	0.00	0.0012	0.00001	0.00	0.05	0.21
Polynoidae	2.0	0.0	3.00	0.00	0.0005	0.00001	0.00	0.02	0.16
Nereidae	4.0	0.0	55.00	0.00	0.0098	0.00011	0.00	0.04	2.84
Nephtys caeca	410.0	0.5	1251.00	0.01	0.0205	0.00243	0.01	3.77	64.65
Chaetopterus variopedatus	151.0	0.2	5.00	0.00	0.0020	0.00001	0.00	1.39	0.26
Ophelia limacina	11.0	0.0	11.00	0.00	0.0007	0.00002	0.00	0.10	0.57
Travisia forbesii	63.0	0.1	74.00	0.00	0.0028	0.00014	0.00	0.58	3.82
Nicomache spp.	5462.0	6.7	2.00	0.00	0.0003	0.00000	0.00	50.23	0.10
Chone cincta	25.0	0.0	50.00	0.00	0.0625	0.00010	0.00	0.23	2.58
Sabella media	4738.0	5.8	477.00	0.01	0.0118	0.00093	0.01	43.57	24.65
Notostomobdella spp.	3.0	0.0	3.00	0.00	0.0004	0.00001	0.00	0.03	0.16
S. groenlandicus	39.0	0.0	11350.00	0.13	3.7394	0.02203	0.13	0.08	0.18
Yoldia scissurata	1.0	0.0	2.00	0.00	0.0006	0.00000	0.00	0.00	0.00
Mytilus edulis	40.0	0.0	10.00	0.00	0.0033	0.00002	0.00	0.08	0.00
Musculus niger	1.0	0.0	10.00	0.00	0.0059	0.00002	0.00	0.00	0.00
Musculus discors	1.0	0.0	1.00	0.00	0.0004	0.00000	0.00	0.00	0.00
Modiolus modiolus	1.0	0.0	40.00	0.00	0.0160	0.00008	0.00	0.00	0.00
Pecten caurinus	1.0	0.0	454.00	0.01	0.5675	0.00088	0.01	0.00	0.01
Pododesmus macrochisma	1.0	0.0	5.00	0.00	0.0015	0.00001	0.00	0.00	0.00

TABLE 4.V

CONTINUED

Taxon Name	Count	% Count	Weight	% Weight	Occ Sta g/m^2	All Sta g/m^2	Biom %	Phyl C %	Phyl W %
Astarte alaskensis	1.0	0.0	20.00	0.00	0.0080	0.00004	0.00	0.00	0.00
Astarte montegui	17.0	0.0	66.00	0.00	0.0135	0.00013	0.00	0.03	0.00
Astarte rollardi	122.0	0.2	679.00	0.01	0.0422	0.00132	0.01	0.24	0.01
Cyclocardia crebricostata	378.0	0.5	927.00	0.01	0.0128	0.00180	0.01	0.76	0.01
Diplodonta aleutica	1.0	0.0	2.00	0.00	0.0007	0.00000	0.00	0.00	0.00
Clinocardium ciliatum	5.0	0.0	1820.00	0.02	0.8273	0.00353	0.02	0.01	0.03
Clinocardium nuttallii	50.0	0.1	13130.00	0.14	0.6079	0.02548	0.14	0.10	0.21
Clinocardium californiense	3.0	0.0	30.00	0.00	0.0075	0.00006	0.00	0.01	0.00
Serripes groenlandicus	504.0	0.6	89288.00	0.98	0.6005	0.17327	0.98	1.01	1.43
Serripes laperousii	238.0	0.3	79145.00	0.87	0.8084	0.15359	0.87	0.48	1.26
Spisula polynyma	25514.0	31.4	5416400.00	59.75	12.5177	10.51116	59.75	51.16	86.48
Macoma calcarea	230.0	0.3	5068.00	0.06	0.2060	0.00984	0.06	0.46	0.08
Macoma middendorffi	510.0	0.6	9206.00	0.10	0.1266	0.01787	0.10	1.02	0.15
Tellina lutea alternidentata	21782.0	26.8	599834.00	6.62	2.2973	1.16405	6.62	43.68	9.58
Tellina nucleoides	1.0	0.0	230.00	0.00	0.0920	0.00045	0.00	0.00	0.00
Siliqua alta	141.0	0.2	11026.00	0.12	0.0958	0.02140	0.12	0.28	0.18
Mya truncata	28.0	0.0	2189.00	0.02	0.1542	0.00425	0.02	0.06	0.03
Mya elegans	7.0	0.0	1874.00	0.02	0.1630	0.00364	0.02	0.01	0.03
Hiatella arctica	71.0	0.1	18.00	0.00	0.0014	0.00003	0.00	0.14	0.00
Panopea generosa	1.0	0.0	60.00	0.00	0.0240	0.00012	0.00	0.00	0.00
Thracia myopsis	1.0	0.0	8.00	0.00	0.0029	0.00002	0.00	0.00	0.00
Solariella obscura	1.0	0.0	1.00	0.00	0.0006	0.00000	0.00	0.00	0.00
Tachyrynchus erosus	1.0	0.0	1.00	0.00	0.0006	0.00000	0.00	0.00	0.00
Amauropsis purpurea	2.0	0.0	4.00	0.00	0.0008	0.00001	0.00	0.00	0.00
Natica clausa	3.0	0.0	10.00	0.00	0.0015	0.00002	0.00	0.01	0.00

TABLE 4.V

CONTINUED

Taxon Name	Count	% Count	Weight	% Weight	Occ Sta g/m^2	All Sta g/m^2	Biom %	Phyl C %	Phyl W %
Velutina undata	1.0	0.0	1.00	0.00	0.	0.00000	0.00	0.00	0.00
Buccinum glaciale	1.0	0.0	4.00	0.00	0.0008	0.00001	0.00	0.00	0.00
Beringius beringi	3.0	0.0	380.00	0.00	0.0594	0.00074	0.00	0.01	0.01
Neptunea lyrata	7.0	0.0	1377.00	0.02	0.2221	0.00267	0.02	0.01	0.02
Neptunea ventricosa	85.0	0.1	13044.00	0.14	0.1637	0.02531	0.14	0.17	0.21
Neptunea heros	76.0	0.1	5358.00	0.06	0.1854	0.01040	0.06	0.15	0.09
Pycnogonida	3.0	0.0	1.00	0.00	0.0004	0.00000	0.00	100.00	100.00
Balanus spp.	2189.0	2.7	6969.00	0.08	0.4249	0.01352	0.08	77.54	3.86
Balanus nubilis	50.0	0.1	120.00	0.00	0.0480	0.00023	0.00	1.77	0.07
Synidotea nodulosa	1.0	0.0	1.00	0.00	0.0003	0.00000	0.00	0.04	0.00
Amphipoda	31.0	0.0	5.00	0.00	0.0004	0.00001	0.00	1.10	0.00
Anonyx spp.	6.0	0.0	7.00	0.00	0.0007	0.00001	0.00	0.21	0.00
Crangon dalli	3.0	0.0	7.00	0.00	0.0008	0.00001	0.00	0.11	0.00
Argis crassa	1.0	0.0	2.00	0.00	0.	0.00000	0.00	0.04	0.00
Paguridae	6.0	0.0	50.00	0.00	0.0152	0.00010	0.00	0.21	0.03
Pagurus ochotensis	118.0	0.1	2650.00	0.03	0.0235	0.00514	0.03	4.18	1.47
Pagurus capillatus	11.0	0.0	155.00	0.00	0.0058	0.00030	0.00	0.39	0.09
Pagurus trigonocheirus	5.0	0.0	125.00	0.00	0.0101	0.00024	0.00	0.18	0.07
Labidochirus splendescens	5.0	0.0	45.00	0.00	0.0023	0.00009	0.00	0.18	0.02
Paralithodes camtschatica	131.0	0.2	130869.00	1.44	1.1602	0.25397	1.44	4.64	72.42
Oregonia gracilis	14.0	0.0	58.00	0.00	0.0026	0.00011	0.00	0.50	0.03
Hyas lyratus	33.0	0.0	1670.00	0.02	0.0564	0.00324	0.02	1.17	0.92
Hyas coarctatus alutaceus	53.0	0.1	5708.00	0.06	0.0910	0.01108	0.06	1.88	3.16
Chionoecetes opilio	3.0	0.0	1140.00	0.01	0.3455	0.00221	0.01	0.11	0.63
Chionoecetes bairdi	35.0	0.0	6542.00	0.07	0.1306	0.01270	0.07	1.24	3.62
Telmessus cheiragonus	99.0	0.1	17814.00	0.20	0.2571	0.03457	0.20	3.51	9.86

TABLE 4.V

CONTINUED

Taxon Name	Count	% Count	Weight	% Weight	Occ Sta g/m^2	All Sta g/m^2	Biom %	Phyl C %	Phyl W %
Erimacrus isenbeckii	29.0	0.0	4774.00	0.07	0.1660	0.01315	0.07	1.03	3.75
Sipunculida	3.0	0.0	70.00	0.00	0.0093	0.00014	0.00	100.00	100.00
Echiurus echiurus alaskanus	67.0	0.1	904.00	0.01	0.0171	0.00175	0.01	100.00	100.00
Ectoprocta	0.	0.	10.00	0.00	0.0030	0.00002	0.00	0.	9.90
Flustridae	0.	0.	19.00	0.00	0.0029	0.00004	0.00	0.	18.81
Dendrobeania spp.	0.	0.	5.00	0.00	0.0010	0.00001	0.00	0.	4.95
Alcyonidium spp.	1.0	0.0	67.00	0.00	0.0059	0.00013	0.00	100.00	66.34
Henricia spp.	1.0	0.0	20.00	0.00	0.0118	0.00004	0.00	0.01	0.00
Asterias amurensis	14419.0	17.7	2433933.00	26.85	7.5729	4.72334	26.85	87.69	96.55
Evasterias echinosoma	37.0	0.0	30104.00	0.33	0.8577	0.05842	0.33	0.23	1.19
Evasterias troschelii	6.0	0.0	4090.00	0.05	2.4059	0.00794	0.05	0.04	0.16
Leptasterias spp.	50.0	0.1	75.00	0.00	0.0441	0.00015	0.00	0.30	0.00
Echinarachnius parma	1769.0	2.2	3095.00	0.03	0.0474	0.00601	0.03	10.76	0.12
Strongylocentrotus droebachiensis	13.0	0.0	242.00	0.00	0.0410	0.00047	0.00	0.08	0.01
Diamphiodia craterodmeta	2.0	0.0	1.00	0.00	0.0006	0.00000	0.00	0.01	0.00
Gorgonocephalus caryi	43.0	0.1	4456.00	0.05	0.1553	0.00865	0.05	0.26	0.18
Stegophiura nodosa	6.0	0.0	6.00	0.00	0.0005	0.00001	0.00	0.04	0.00
Cucumaria spp.	87.0	0.1	40361.00	0.45	1.2692	0.07833	0.45	0.53	1.60
Cucumaria calcigera	11.0	0.0	4545.00	0.05	0.8264	0.00882	0.05	0.07	0.18
Urochordata	0.	0.	5370.00	0.06	0.3399	0.01042	0.06	0.	6.18
Chelyosoma spp.	2.0	0.0	70.00	0.00	0.0125	0.00014	0.00	0.40	0.08
Styela rustica macrenteron	227.0	0.3	3160.00	0.03	0.0751	0.00613	0.03	45.95	3.64
Boltenia ovifera	263.0	0.3	78258.00	0.86	1.9134	0.15187	0.86	53.24	90.08
Salpidae	2.0	0.0	20.00	0.00	0.0061	0.00004	0.00	0.40	0.02
Gymnocanthus spp.	2.0	0.0	160.00	0.00	0.0308	0.00031	0.00	11.76	3.58

TABLE 4.V

CONTINUED

Taxon Name	Count	% Count	Weight	% Weight	Occ Sta g/m^2	All Sta g/m^2	Biom %	Phyl C %	Phyl W %
Myoxocephalus spp.	1.0	0.0	454.00	0.01	0.1376	0.00088	0.01	5.88	10.16
Ammodytes hexapterus	2.0	0.0	20.00	0.00	0.0118	0.00004	0.00	11.76	0.45
Hippoglossoides robustus	7.0	0.0	1054.00	0.01	0.0843	0.00205	0.01	41.18	23.59
Lepidopsetta bilineata	5.0	0.0	2780.00	0.03	0.2780	0.00539	0.03	29.41	62.22

[1] Weight is reported in grams.

TABLE 4.VI

OCCURRENCES OF EACH SPECIES

Taxonomic Name	Occurrence	% of all occur.	% of all stations	Dist. (km)
Porifera	11	0.818	5.263	28.10
Hydrozoa	6	0.446	2.871	8.20
Scyphozoa	5	0.372	2.392	16.40
Eunephthya rubiformis	7	0.520	3.349	16.50
Actiniidae	14	1.041	0.478	2.60
Rhynchocoela	6	0.446	2.871	13.30
Polychaeta	3	0.223	1.435	3.40
Polynoidae	2	0.149	0.957	5.60
Nereidae	4	0.297	1.914	5.60
Nephtys caeca	27	2.007	12.919	60.90
Chaetopterus variopedatus	3	0.223	1.435	2.50
Ophelia limacina	7	0.520	3.349	16.70
Travisia forbesii	10	0.743	4.785	26.20
Nicomache spp.	18	1.338	8.612	7.50
Chone cincta	1	0.074	0.478	0.80
Sabella media	34	2.528	16.268	40.30
Notostomobdella spp.	3	0.223	1.435	7.50
Yoldia spp.	1	0.074	0.478	0.
Yoldia scissurata	1	0.074	0.478	3.30
Mytilus edulis	1	0.074	0.478	3.00
Musculus niger	1	0.074	0.478	1.70
Musculus discors	1	0.074	0.478	2.40
Modiolus modiolus	1	0.074	0.478	2.50
Pecten caurinus	1	0.074	0.478	0.80
Pododesmus machrochisma	1	0.074	0.478	3.30
Astarte alaskensis	1	0.074	0.478	2.50
Astarte montegui	3	0.223	1.435	4.90
Astarte rollandi	7	0.520	3.349	16.10
Cyclocardia crebricostata	31	2.305	14.833	72.70
Diplodonta aleutica	1	0.074	0.478	2.80
Clinocardium ciliatum	1	0.074	0.478	2.20
Clinocardium nuttallii	10	0.743	4.785	21.60
Clinocardium californiense	2	0.149	0.957	4.00
Serripes groenlandicus	51	3.781	24.411	152.00
Serripes laperousii	44	3.271	21.053	97.90
Spisula polynyma	178	13.234	85.167	432.70
Macoma spp.	1	0.074	0.478	0.
Macoma calcarea	7	0.520	3.349	24.60
Macoma middendorfii	34	2.528	16.267	76.70

TABLE 4.VI

CONTINUED

Taxonomic Name	Occurrence	% of all occur.	% of all stations	Dist. (km)
Tellina lutea alternidentata	109	8.104	52.153	263.60
Siliqua alta	47	3.494	22.488	115.10
Mya truncata	7	0.520	3.349	14.20
Mya elegans	6	0.446	2.871	11.50
Hiatella arctica	5	0.372	2.392	12.80
Panopea generosa	1	0.074	0.478	2.50
Thracia myopsis	1	0.074	0.478	2.80
Solariella obscura	1	0.074	0.478	1.70
Tachyrynchus erosus	1	0.074	0.478	1.70
Amauropsis purpurea	1	0.074	0.478	5.00
Natica clausa	3	0.223	1.435	6.70
Velutina undata	1	0.074	0.478	0.
Buccinum glaciale	1	0.074	0.478	5.00
Beringius beringi	3	0.223	1.435	6.40
Neptunea lyrata	3	0.223	1.435	6.20
Neptunea ventricosa	23	1.710	11.005	79.70
Neptunea heros	11	0.818	5.263	28.29
Pycnogonida	1	0.074	0.478	2.50
Balanus spp.	24	1.784	11.483	16.40
Balanus balanus	1	0.074	0.478	0.
Balanus nubilis	2	0.149	0.957	2.50
Synidotea nodulosa	1	0.074	0.478	3.30
Amphipoda	4	0.297	1.914	12.40
Anonyx spp.	4	0.297	1.914	10.00
Caprellidae	6	0.446	2.871	0.
Crangon dalli	3	0.223	1.435	9.10
Argis crassa	1	0.074	0.478	0.
Paguridae	1	0.074	0.478	3.30
Pagurus ochotensis	46	3.420	22.010	112.90
Pagurus capillatus	9	0.669	4.306	26.50
Pagurus trigonocheirus	4	0.297	1.914	12.40
Labidochirus splendescens	5	0.372	2.392	19.90
Paralithodes camtschatica	42	3.123	20.096	112.80
Oregonia gracilis	11	0.818	5.263	22.00
Hyas lyratus	12	0.892	5.742	29.60
Hyas coarctatus alutaceus	20	1.487	9.569	62.70
Chionoecetes opilio	1	0.074	0.478	3.30
Chionoecetes bairdi	16	1.190	7.656	50.10
Telmessus cheiragonus	34	2.528	16.268	69.30
Erimacrus isenbeckii	14	1.041	6.699	40.80
Sipunculida	3	0.223	1.435	7.50
Echiurus echiurus alaskanus	22	1.636	10.526	52.90
Ectoprocta	2	0.149	0.957	3.30

TABLE 4.VI

CONTINUED

Taxonomic Name	Occurrence	% of all occur.	% of all stations	Dist. (km)
Flustridae	2	0.149	0.957	6.30
Dendrobeania spp.	1	0.074	0.478	5.00
Alcyonidium spp.	5	0.372	2.392	11.40
Henricia spp.	1	0.074	0.478	1.70
Asterias amurensis	130	9.665	62.201	321.40
Evasterias echinosoma	15	1.115	7.177	35.10
Evasterias troschelli	1	0.074	0.478	1.70
Leptasterias spp.	1	0.074	0.478	1.70
Echinarachnius parma	38	2.825	18.182	65.30
Strongylocentrotus droebachiensis	6	0.446	2.871	5.90
Diamphiodia craterometa	1	0.074	0.478	1.70
Gorgonocephalus caryi	9	0.669	4.306	28.70
Stegophiura nodosa	5	0.372	2.392	11.20
Cucumaria spp.	16	1.190	7.656	31.80
Cucumaria calcigera	2	0.149	0.957	5.50
Urochordata	6	0.446	2.871	15.80
Chelyosoma spp.	2	0.149	0.957	5.60
Styela rustica macrenteron	15	1.115	7.177	42.10
Boltenia ovifera	21	1.561	10.048	40.90
Salpidae	1	0.074	0.478	3.30
Gymnocanthus spp.	2	0.149	0.957	5.20
Myoxocephalus spp.	1	0.074	0.478	3.30
Ammodytes hexapterus	1	0.074	0.478	1.70
Hippoglossoides robustus	5	0.372	2.392	12.50
Lepidopsetta bilineata	4	0.297	1.914	10.00

Total distance fished: 515.30 km

Tow or dredge mouth width: 1.00 m

Number of successful stations: 209

groenlandicus, *S. laperousii*, *Macoma middendorffi*, *Tellina lutea*, *Echinarachnius parma*, *Boltenia ovifera* and *Styela rustica macrenteron* (Feder *et al.*, 1978c). Species commonly associated with *S. polynyma* in the mid-shelf region in 45-55 m depths were *Neptunea ventricosa*, *N. heros*, *Asterias amurensis* and *Macoma calcarea*.

Seventeen of the most common invertebrate species were chosen for further comparison with sediment size: the polychaetes *Nephtys caeca*, *Nicomache* sp. and *Sabella media*; the pelecypods (clams) *Serripes groenlandicus*, *Serripes laperousii*, *Spisula polynyma*, *Astarte rollandi*, *Cyclocardia crebricostata*, *Macoma calcarea*, *Macoma middendorffi* and *Tellina lutea*; the gastropods *Neptunea ventricosa* and *Neptunea heros*; the echinoderms *Asterias amurensis* and *Echinarachnius parma*; the tunicates *Styela rustica macrenteron* and *Boltenia ovifera*.

The distributions of the polychaetes *Nephtys caeca*, *Nicomache* spp. and *Sabella media* were associated with coarse-medium sands at 18-47 m depth[1]. *Nephtys caeca* was concentrated between Port Heiden and Dublin Bay (Fig. 4.2). *Nicomache* sp. was concentrated from Port Heiden to Port Moller (Fig. 4.3), while *S. media* was concentrated from Ugashik Bay to Port Moller (Fig. 4.4). Both *N. caeca* and *S. media* had reduced numbers in the northeastern portion of the sampling area (Appendix 4.A).

Distribution of the pelecypods were associated with coarse-medium sands and depths of 18-55 m. *Astarte rollandi* was concentrated from Port Heiden to Port Moller (Fig. 4.5). *Cyclocardia crebricostata* was concentrated from Ugashik Bay to Port Moller, with the remainder distributed on the mid-shelf (Fig. 4.6). *Serripes groenlandicus* was concentrated in the mid-shelf with the remainder distributed from Ugashik Bay to Dublin Bay (Fig. 4.7). *Serripes laperousii* was concentrated in the nearshore area, extending from Ugashik Bay to False Pass, Unimak Island (Fig. 4.8). *Spisula polynyma* was concentrated from Port Heiden to Port Moller with patchy distributions on the mid-shelf and southwest of Port Moller to Dublin Bay (Fig. 4.9; Fig. 2.29). Three species of Tellinidae were associated with coarse-medium sands in 18-55 m depths. *Macoma calcarea* had a limited concentration on

---

[1] See Figures 2.2-2.6 for sediment distributions.

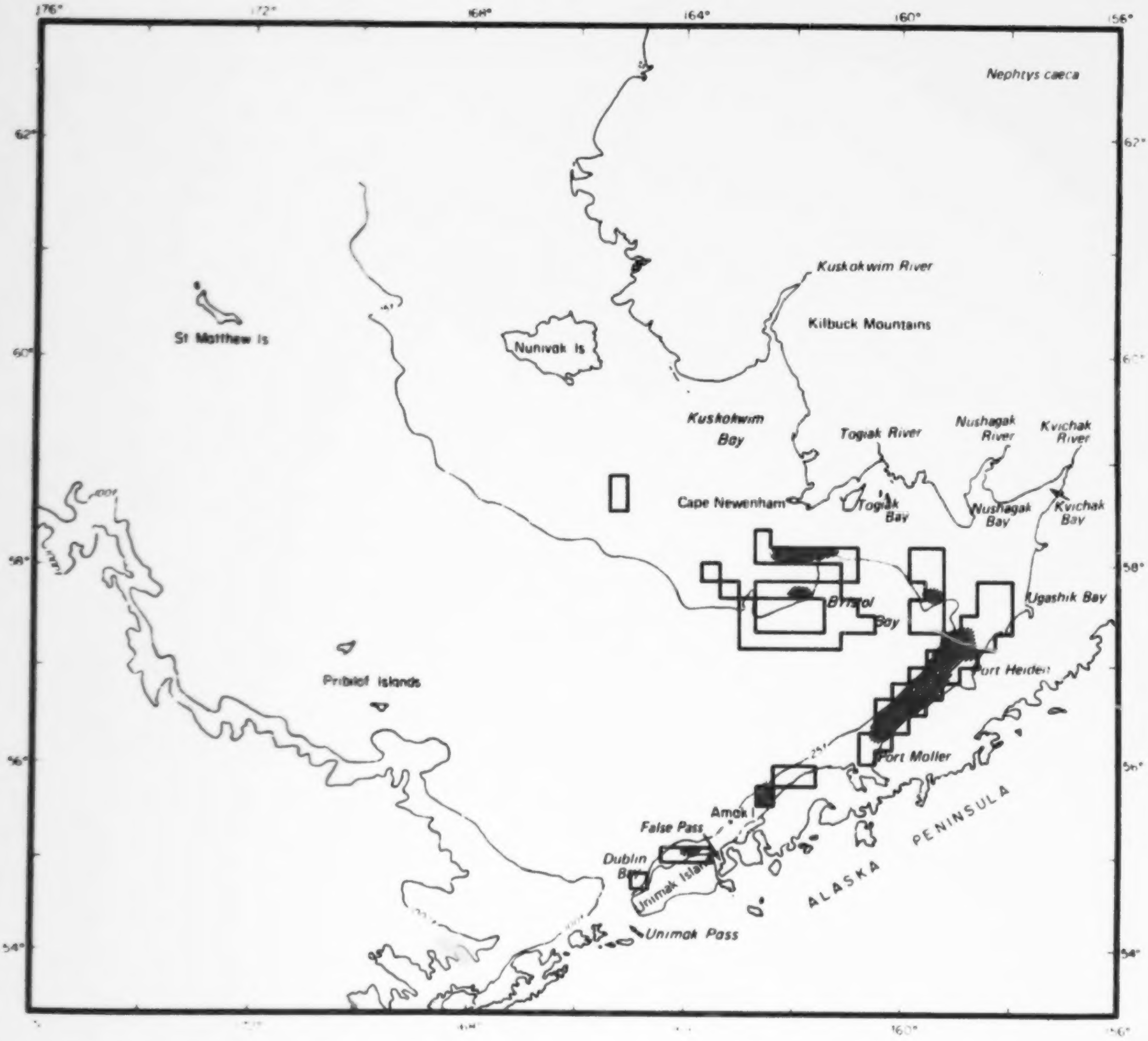

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Nephtys caeca
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.2. The distribution of the polychaete, *Nephtys caeca*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The polychaete distribution is shown by oblique-lined patterns within the enclosure.

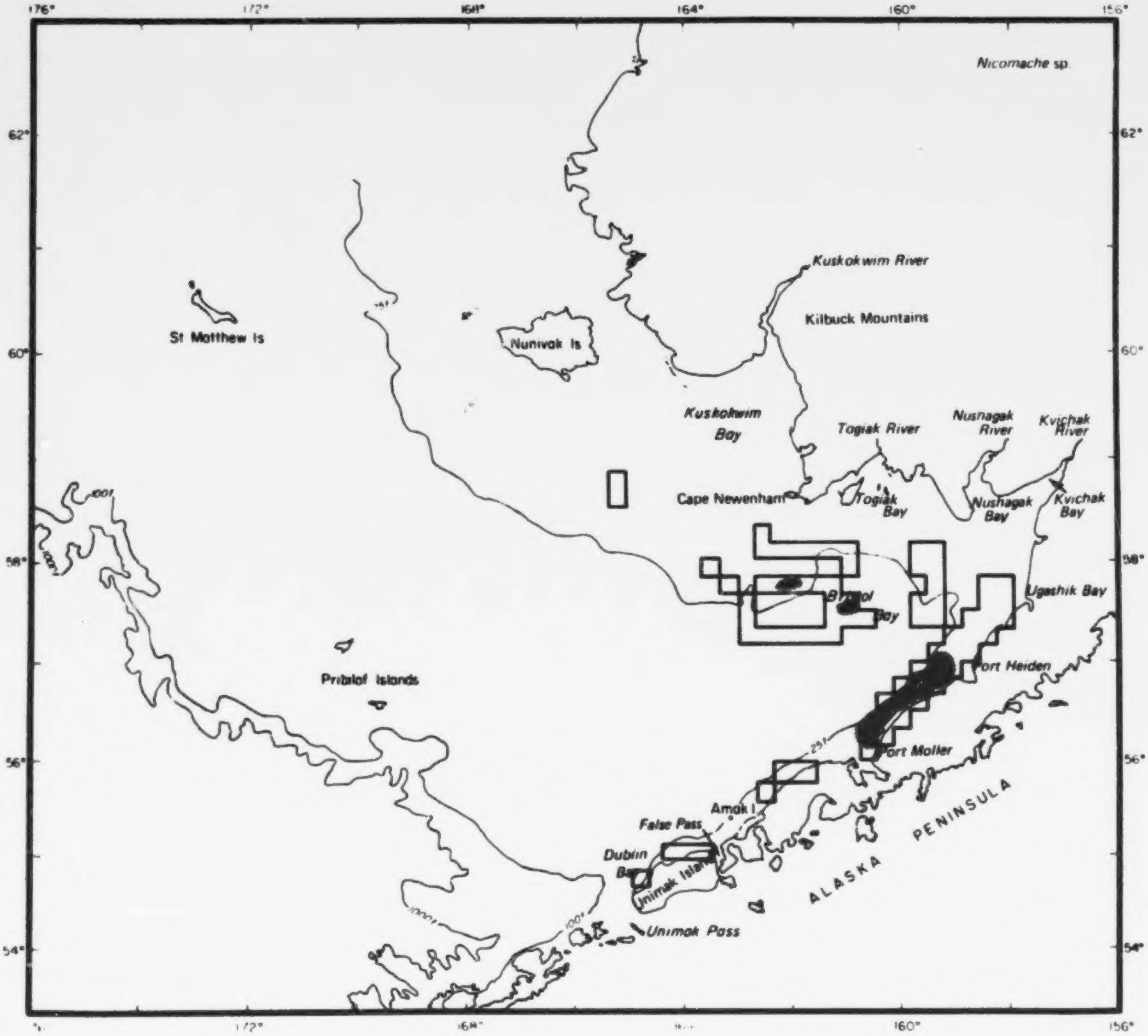
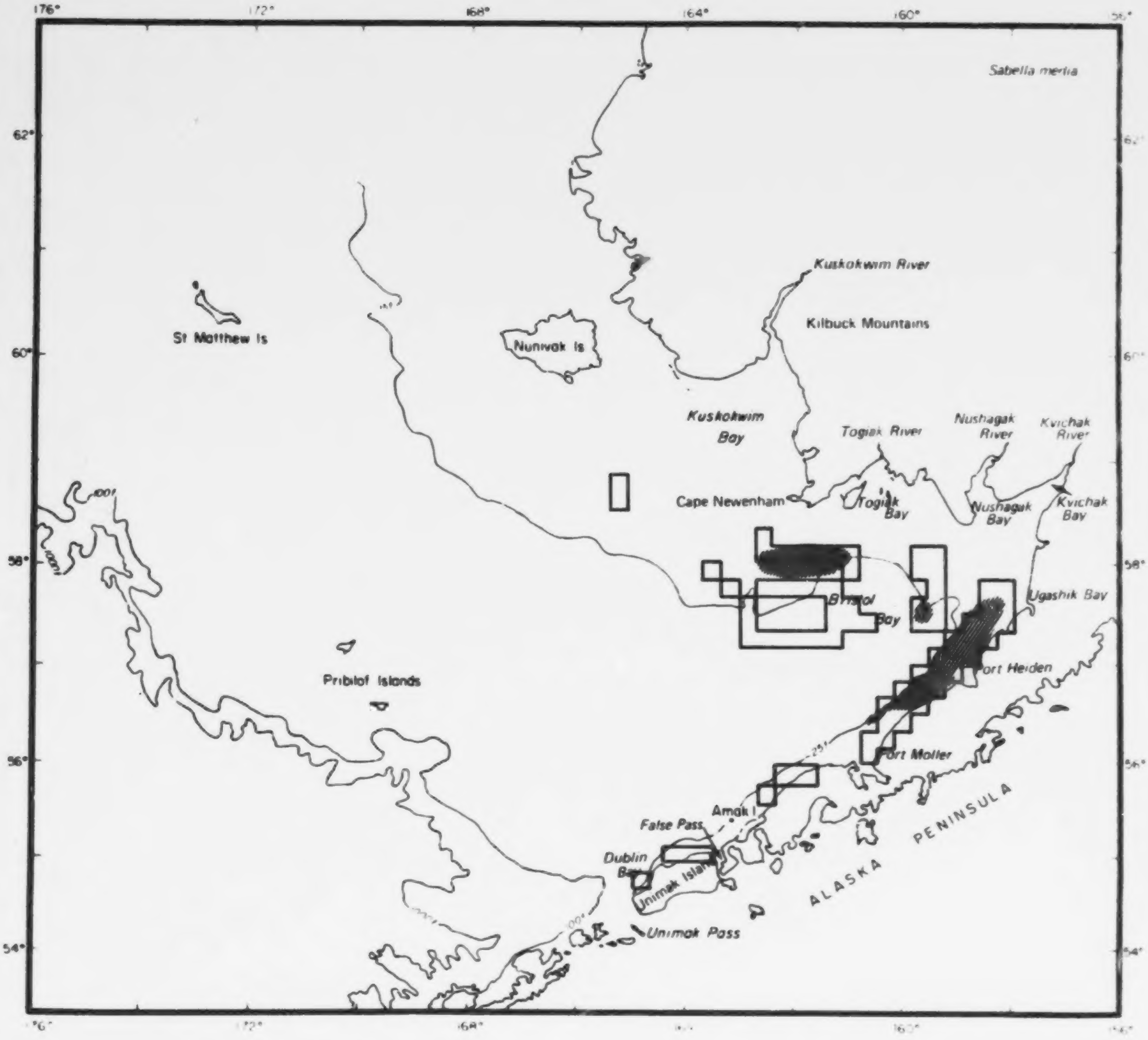

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Nicomache sp.
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA
25f
100f
1000f

Figure 4.3. The distribution of the polychaete, *Nicomache* sp., taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The polychaete distribution is shown by oblique-lined patterns within the enclosure.



176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Sabella media
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA
100
25

Figure 4.4. The distribution of the polychaete, *Sabella media,* taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The polychaete distribution is shown by oblique-lined patterns within the enclosure.

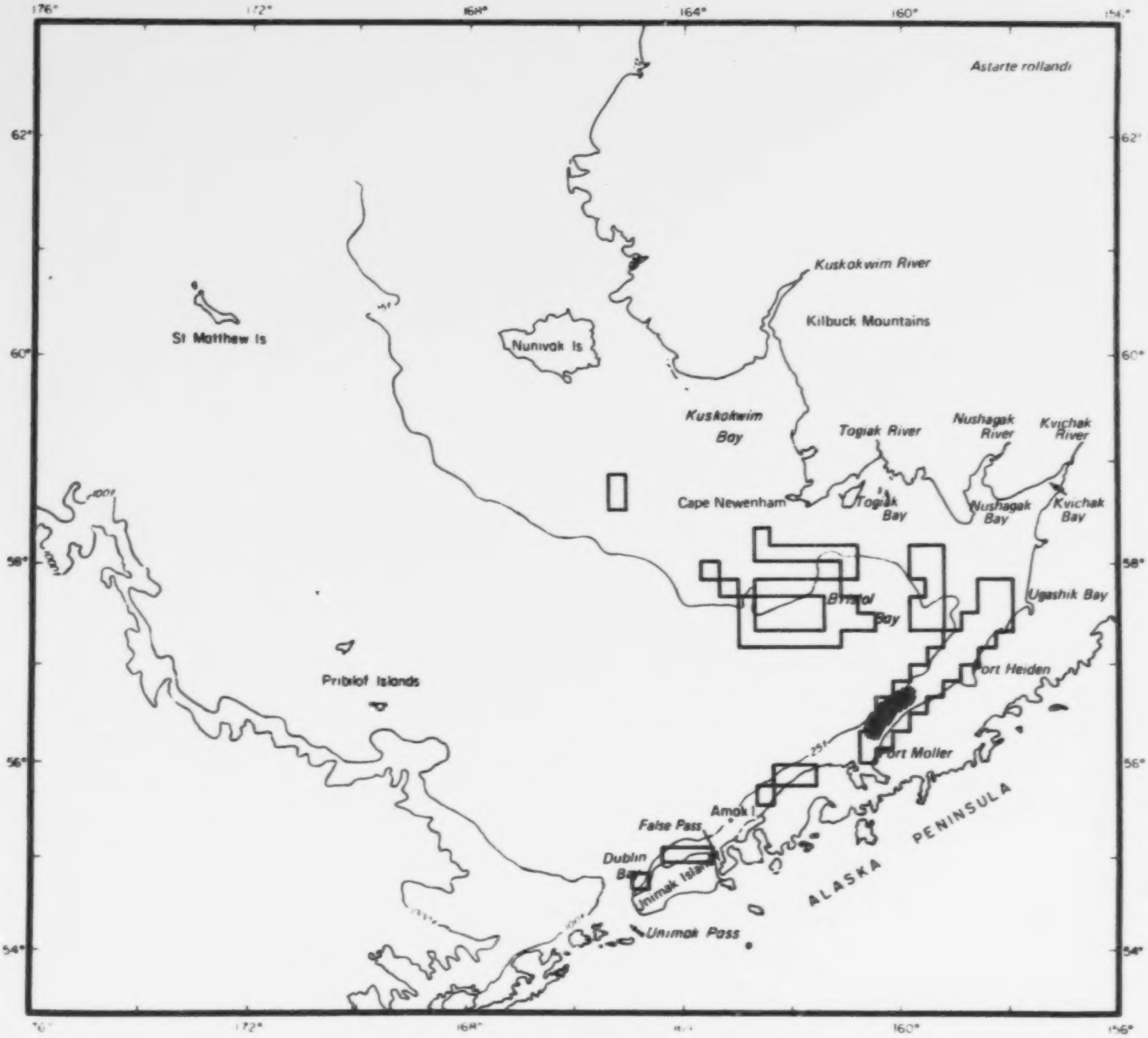

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Astarte rollandi
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I.
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.5. The distribution of the clam. *Astarte rollandi*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.

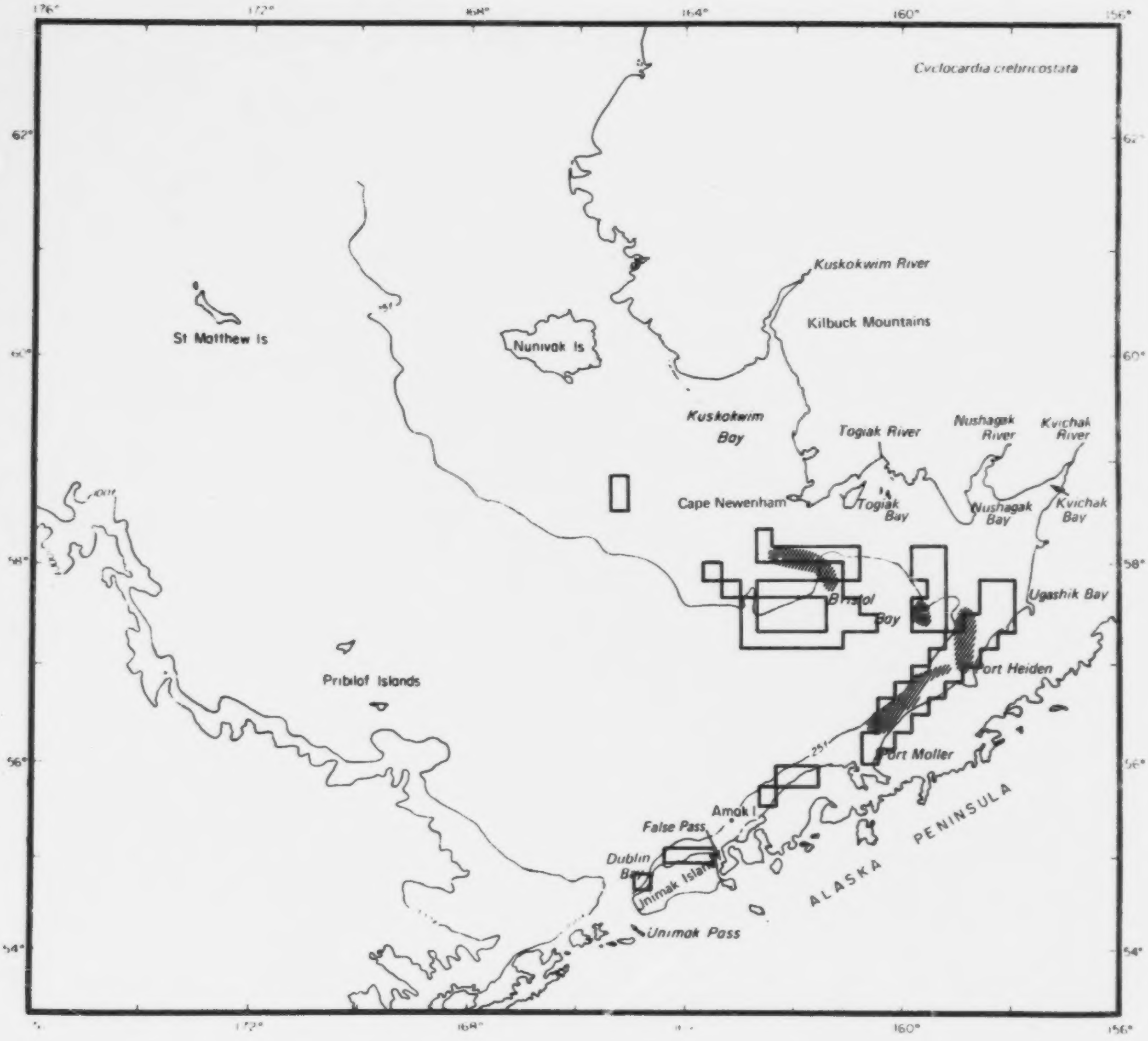

Cyclocardia crebricostata
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.6. The distribution of the cockle, *Cyclocardia crebricostata*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The cockle distribution is shown by oblique-lined patterns within the enclosure.

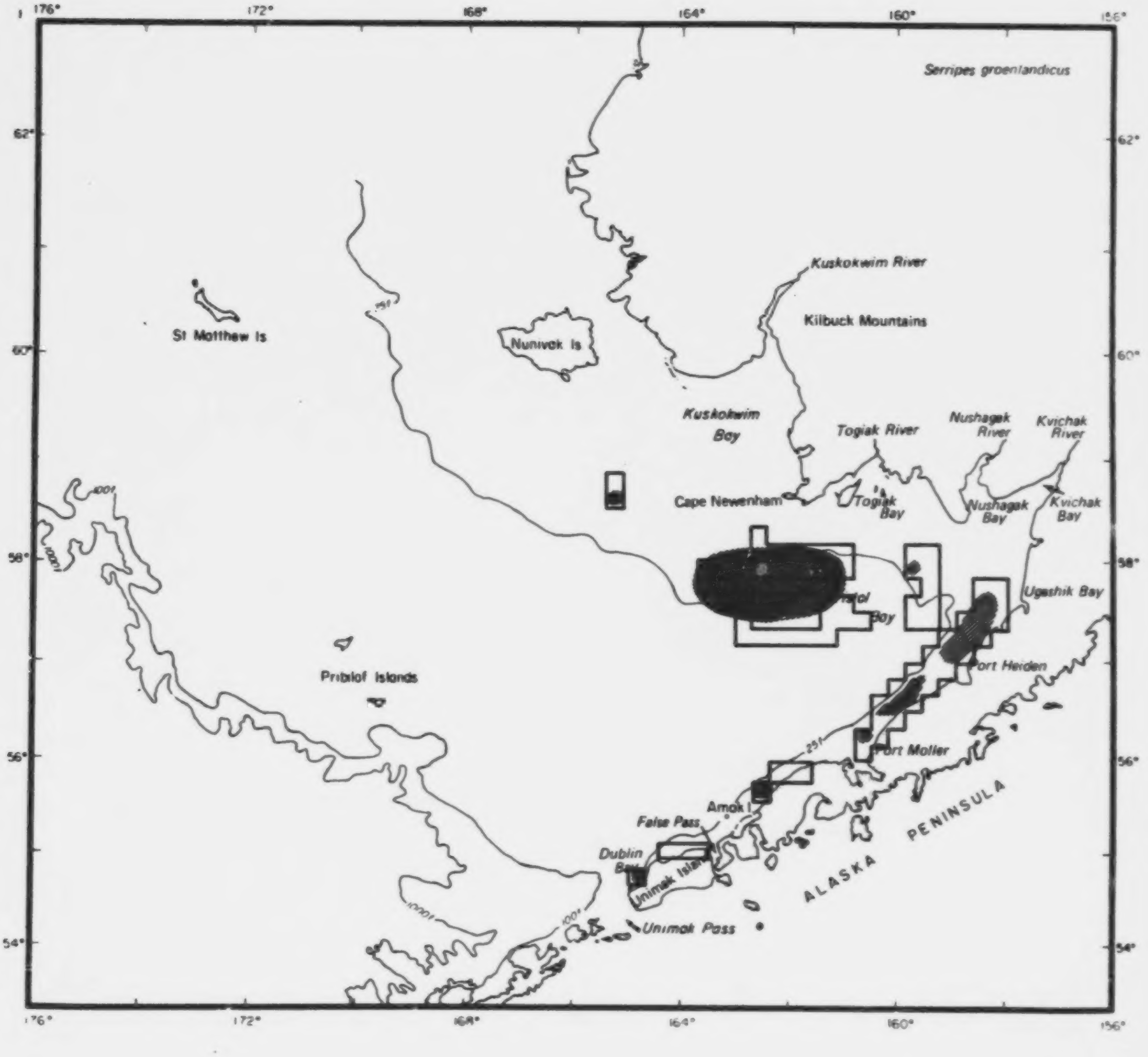

Serripes groenlandicus
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Bristol Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA
25f
100f
1000f

Figure 4.7. The distribution of the clam, *Serripes groenlandicus*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.

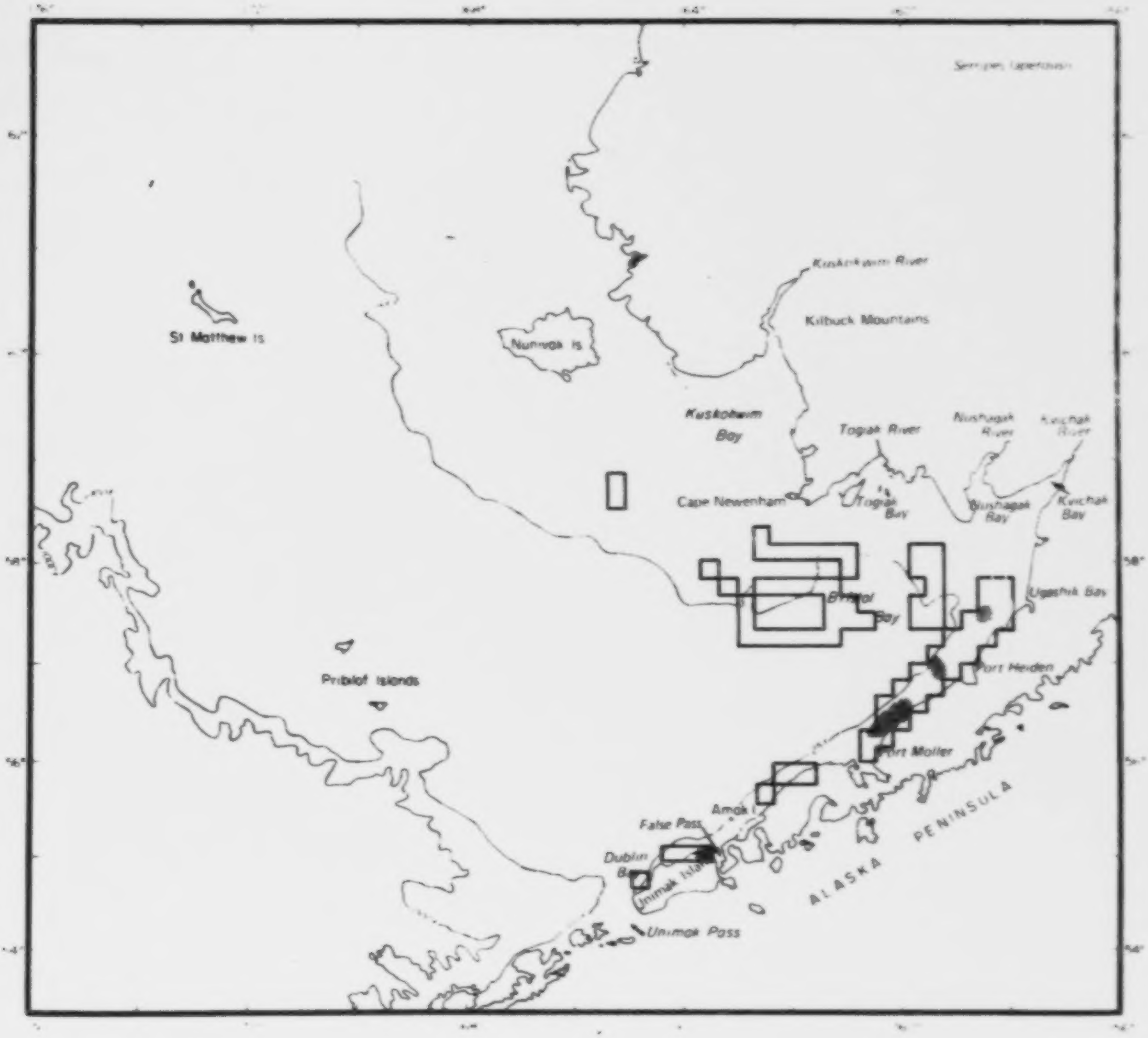

Serripes laperousii
Kuskokwim River
Kilbuck Mountains
Nunivak Is
St Matthew Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA
62°
58°
56°
54°

Figure 4.8. The distribution of the clam, *Serripes laperousii*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.

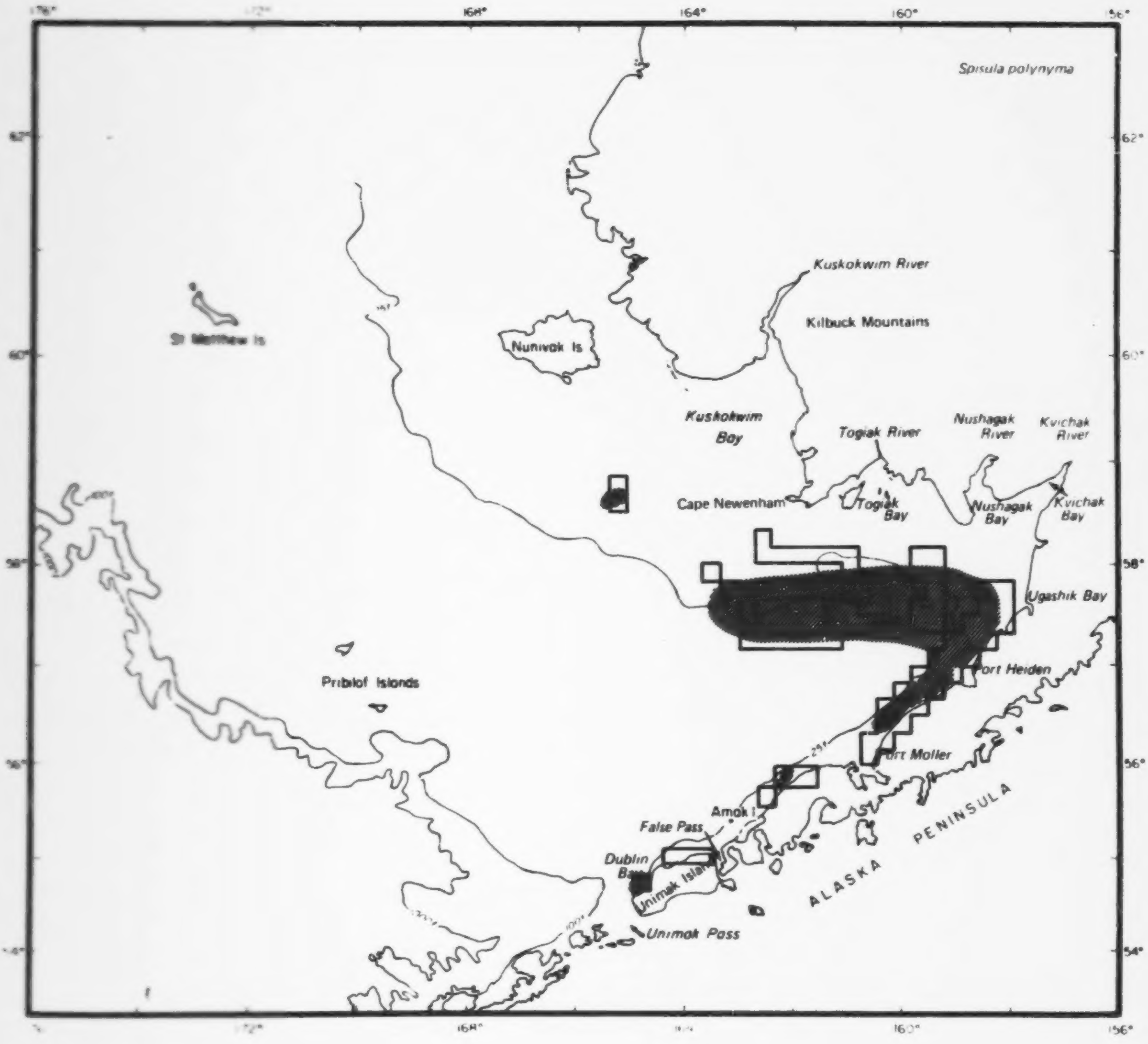

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Spisula polynyma
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I.
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.9. The distribution of the clam, *Spisula polynyma*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.

the mid-shelf and False Pass (Fig. 4.10; Fig. 2.17). *Macoma middendorffi* was concentrated from Port Heiden to Port Moller with limited numbers on the mid-shelf (Fig. 4.11). *Tellina lutea* was concentrated in the mid-shelf and from Ugashik Bay to Port Moller with patchy distributions southwest of Port Moller to Dublin Bay (Fig. 4.12; Fig. 2.6).

Distribution of the gastropods were associated with medium-fine sands, located in 18-47 m depths. The gastropods *Neptunea heros* exclusively occupied the mid-shelf region; the only exception being *N. ventricosa* which occurred southwest of Port Moller (Figs. 4.13, 4.14).

The echinoderms *Asterias amurensis* and *Echinarachnius parma* were concentrated on the mid-shelf and from Ugashik Bay to Port Moller (Figs. 4.15, 4.16; Fig. 3.5). Distribution of the echinoderms were associated with coarse-medium sands located in 18-47 m depths.

Distribution of the tunicates were associated with coarse-medium sands, located in 18-47 m depths. *Boltenia ovifera* and *Styela rustica macrenteron* were concentrated on the mid-shelf and from Ugashik Bay to Port Moller (Figs. 4.17, 4.18; Fig. 3.9).

The cobble and boulders underlying the sand-gravel substrate located in the outlying areas of bays, when compared to the coarse-medium sands located between the latter areas and the mid-shelf, showed no obvious difference in species numbers and biomass (unpub. observations; OCSEAP benthic data on file with NODC; Appendix 4.A).

VII. DISCUSSION

The invertebrates taken by hydraulic dredge in the coarse to medium sand of the nearshore region at depths of approximately 16-55 m in the southeastern Bering Sea only modestly expanded the species list available from the studies conducted in the southeastern Bering Sea using a van Veen grab (Section 2), pipe dredge (Section 2), and trawl (Feder *et al.*, 1978a). Seven additional species were collected: the polychaete *Chaetopterus variopedatus*; the clams *Mya truncata, Panope generosa*; the gastropods *Amauropsis purpurea, Velutina undata*; the barnacle *Balanus nubilis* and the isopod *Synodotea nodulosa* (Table 4.5). It appears, based on our sampling activities,

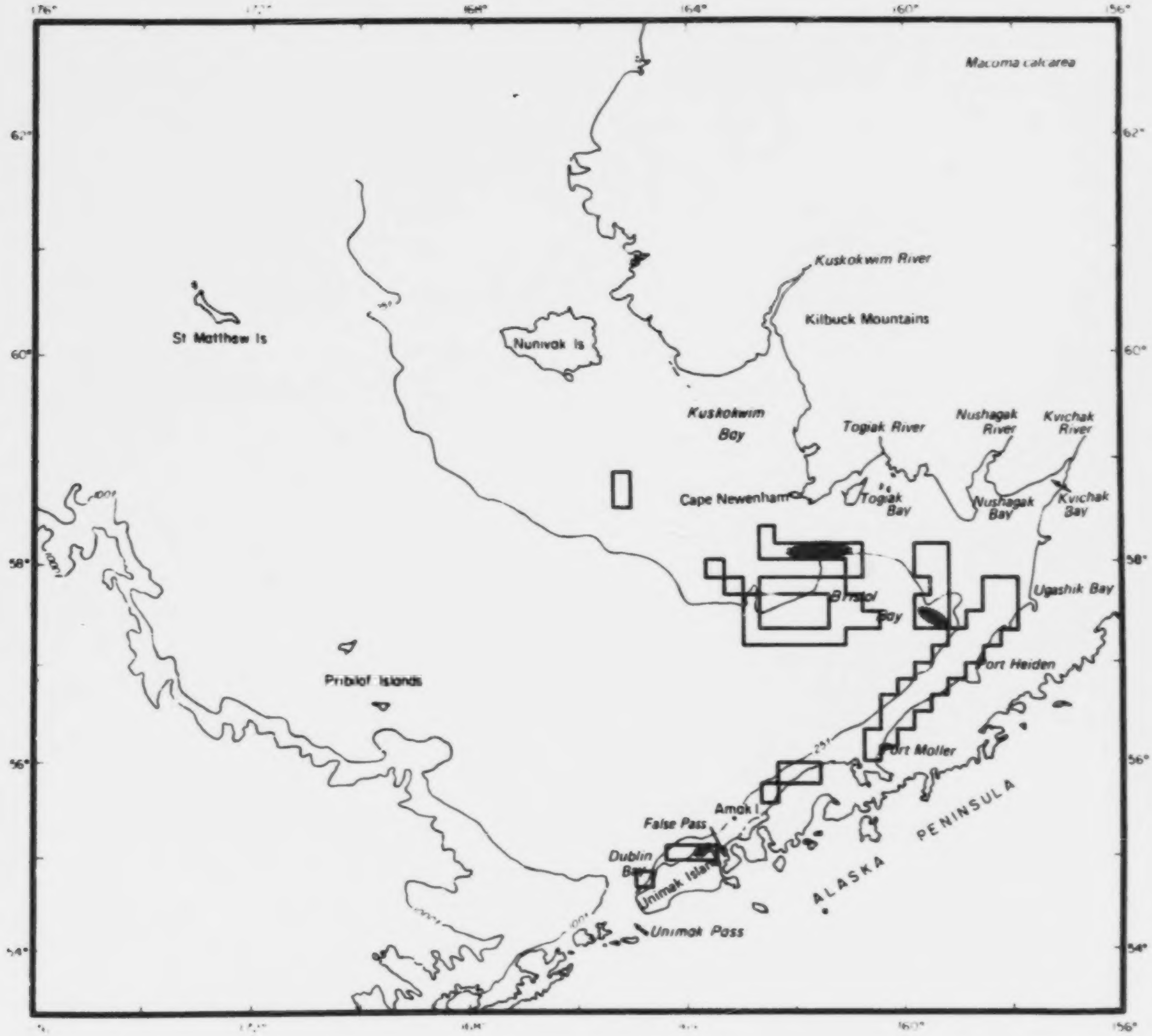

Macoma calcarea
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
St Matthew Is
Nunivak Is
Kuskokwim River
Kilbuck Mountains
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.10. The distribution of the clam, *Macoma calcarea*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.

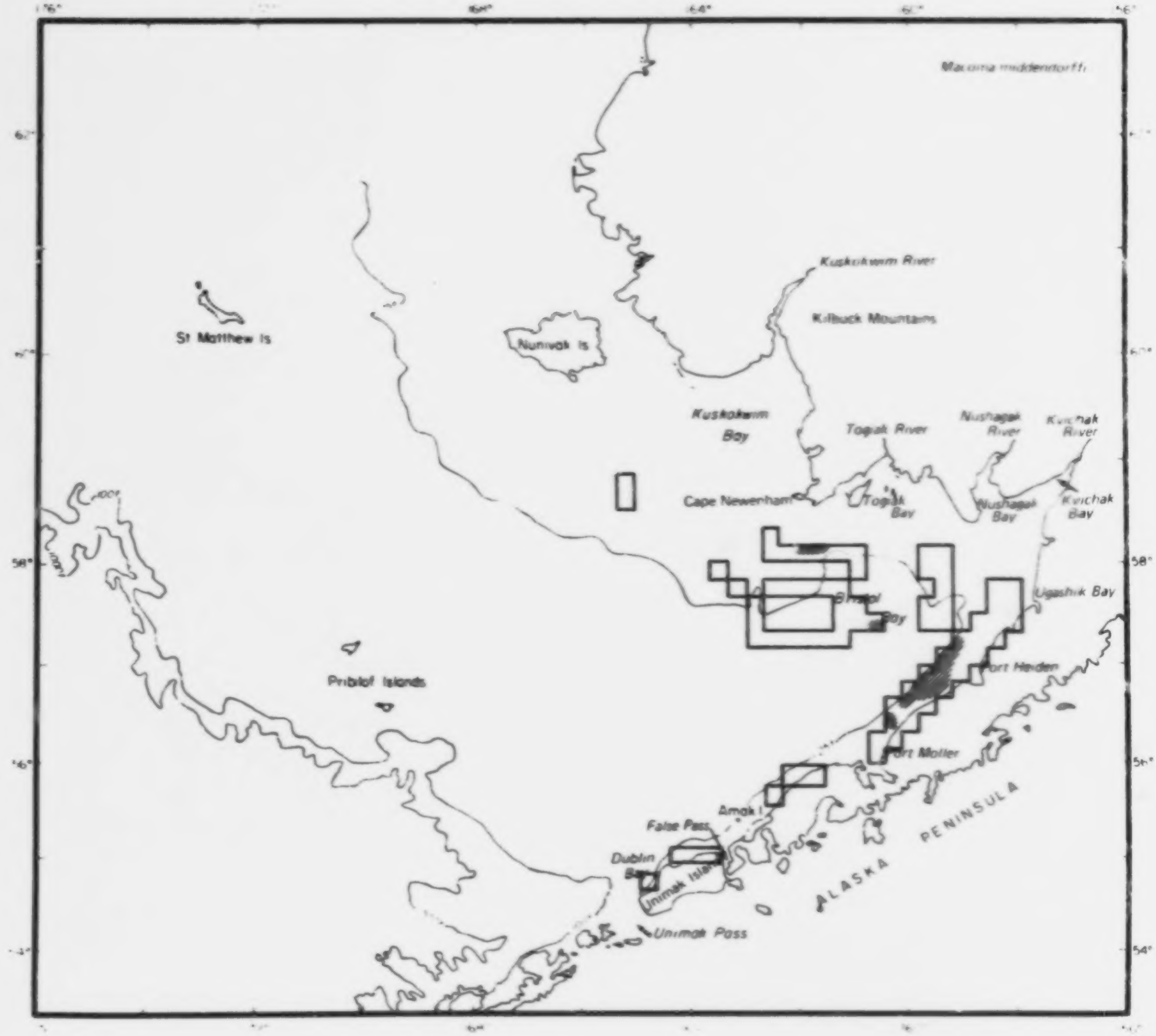

Macoma middendorffi
176°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.11. The distribution of the clam, *Macoma middendorffi*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.

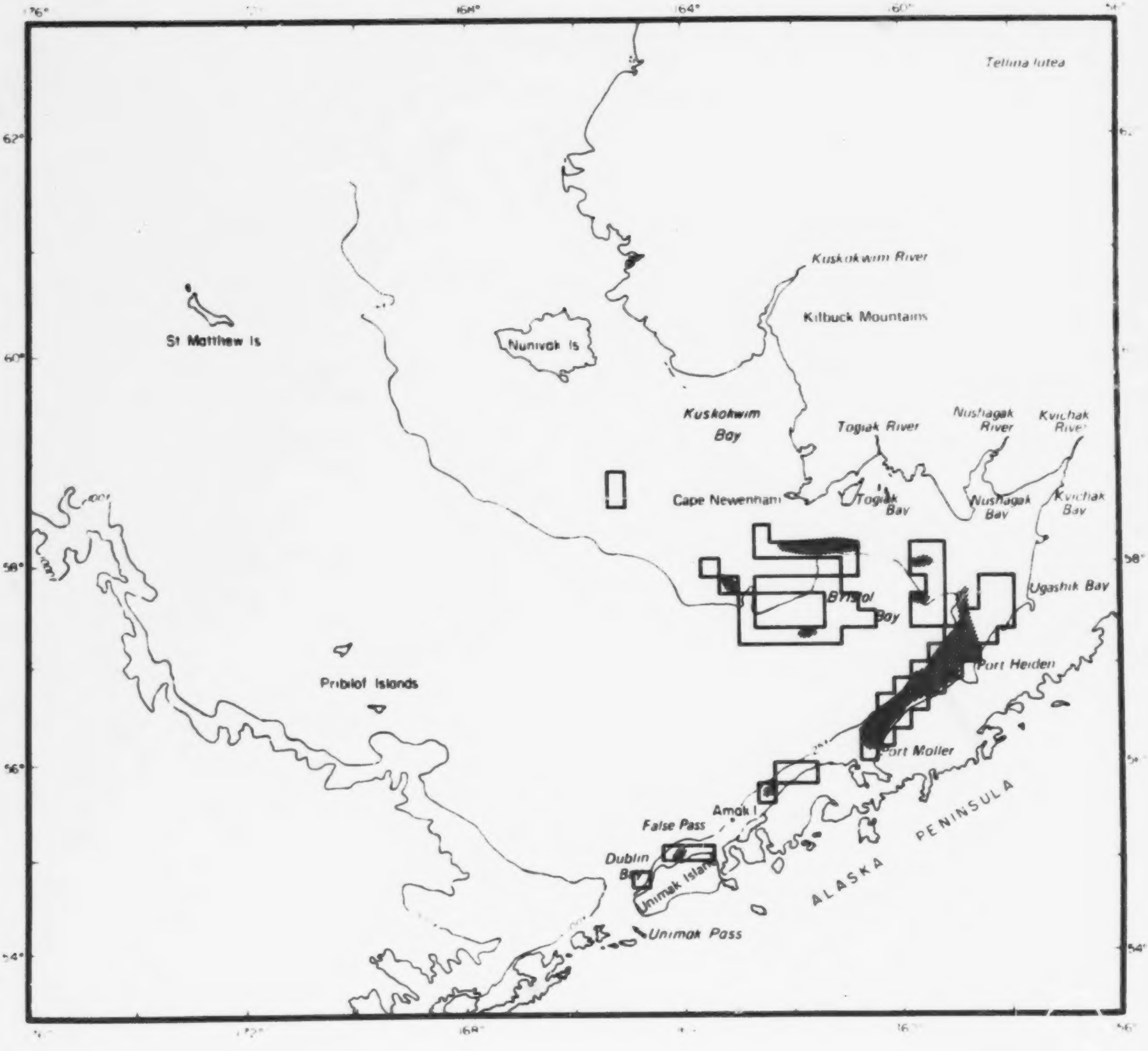
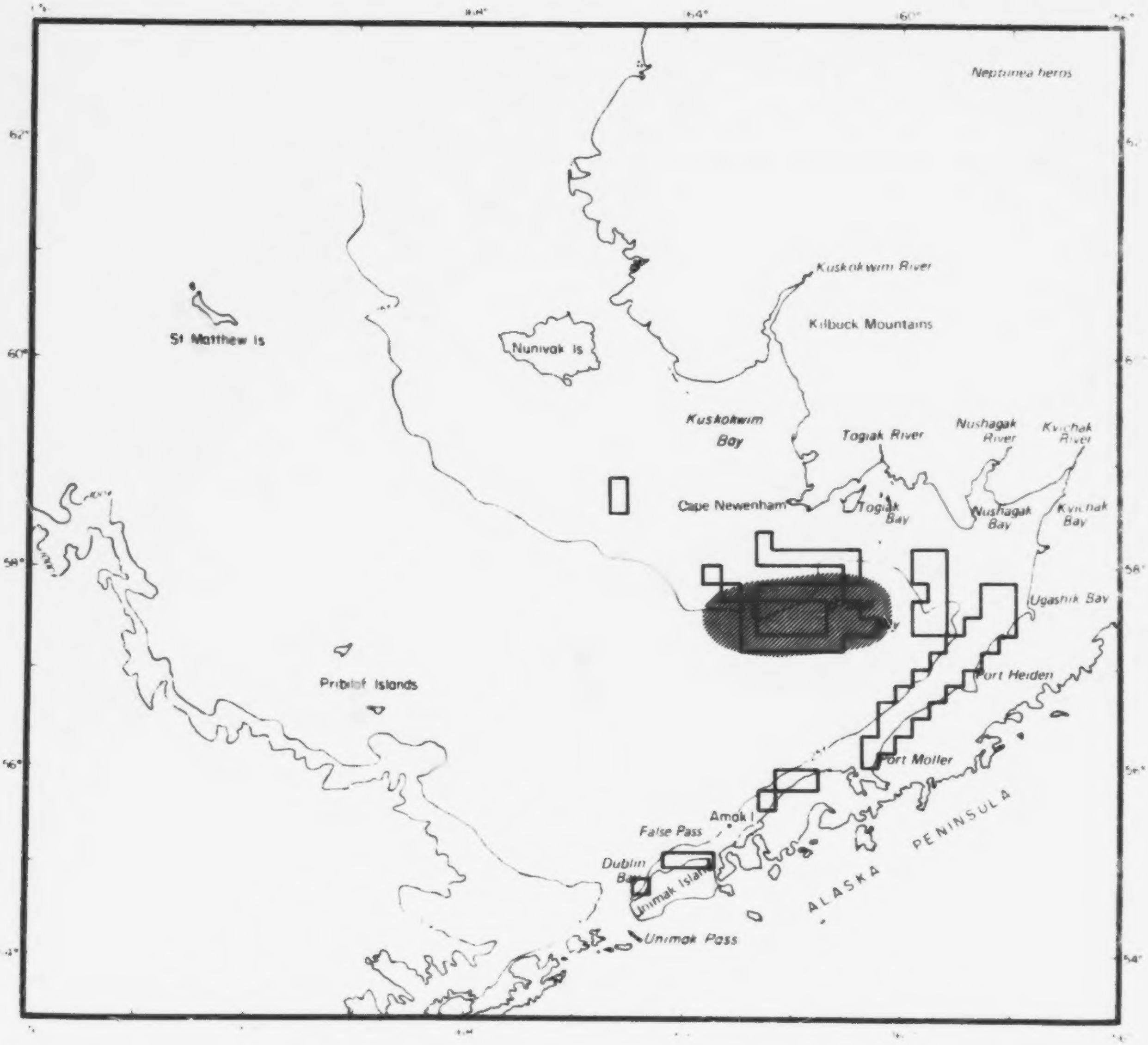

Tellina lutea
62°
60°
58°
56°
54°
168°
164°
160°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.12. The distribution of the clam, *Tellina lutea*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The clam distribution is shown by oblique-lined patterns within the enclosure.



164°
160°
62°
60°
58°
56°
Neptunea heros
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.13. The distribution of the snail, *Neptunea heros*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The snail distribution is shown by oblique-lined patterns within the enclosure.

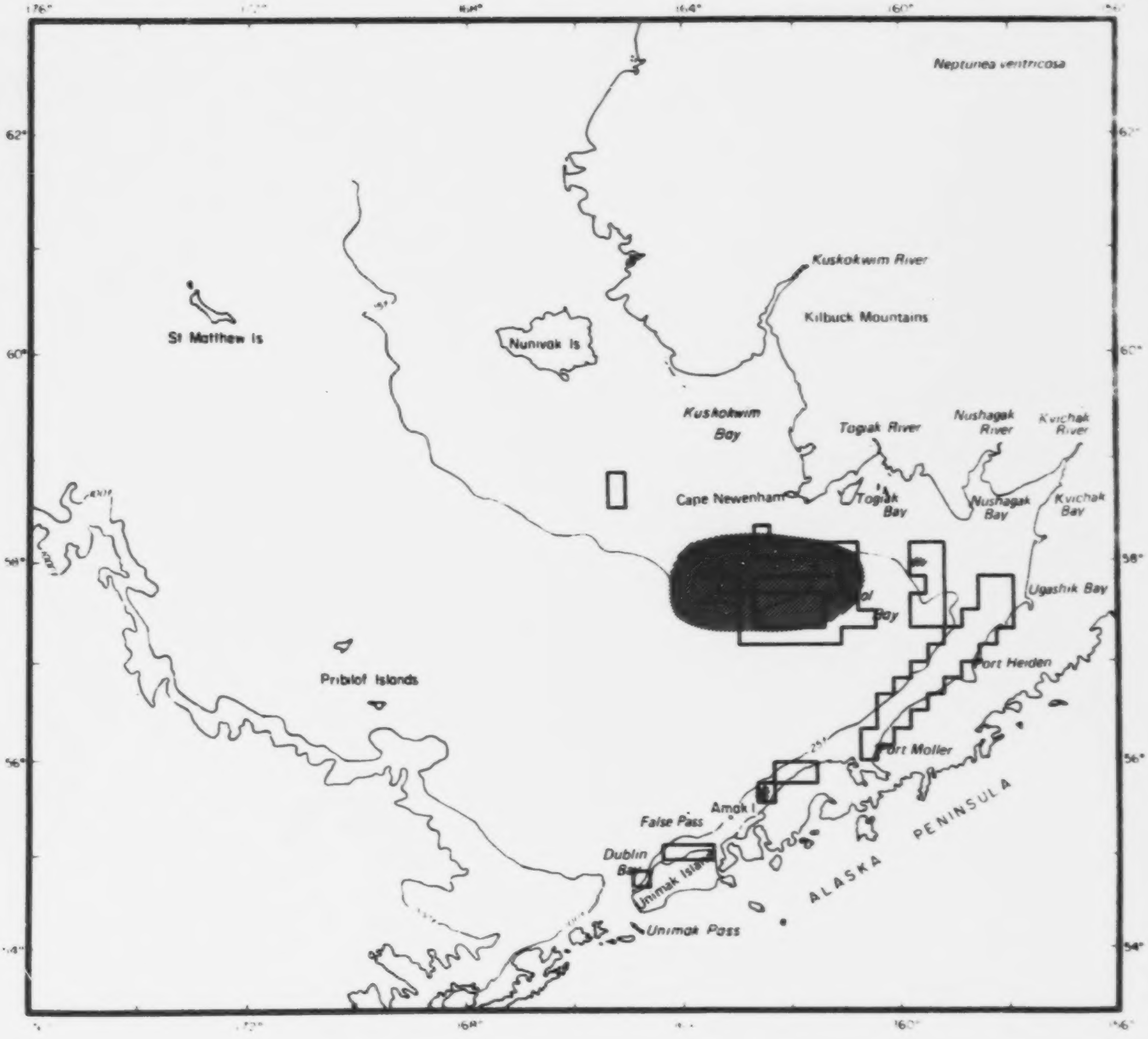

Neptunea ventricosa
176°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA
172°
168°
160°
156°

Figure 4.14. The distribution of the snail, *Neptunea ventricosa*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The snail distribution is shown by oblique-lined patterns within the enclosure.

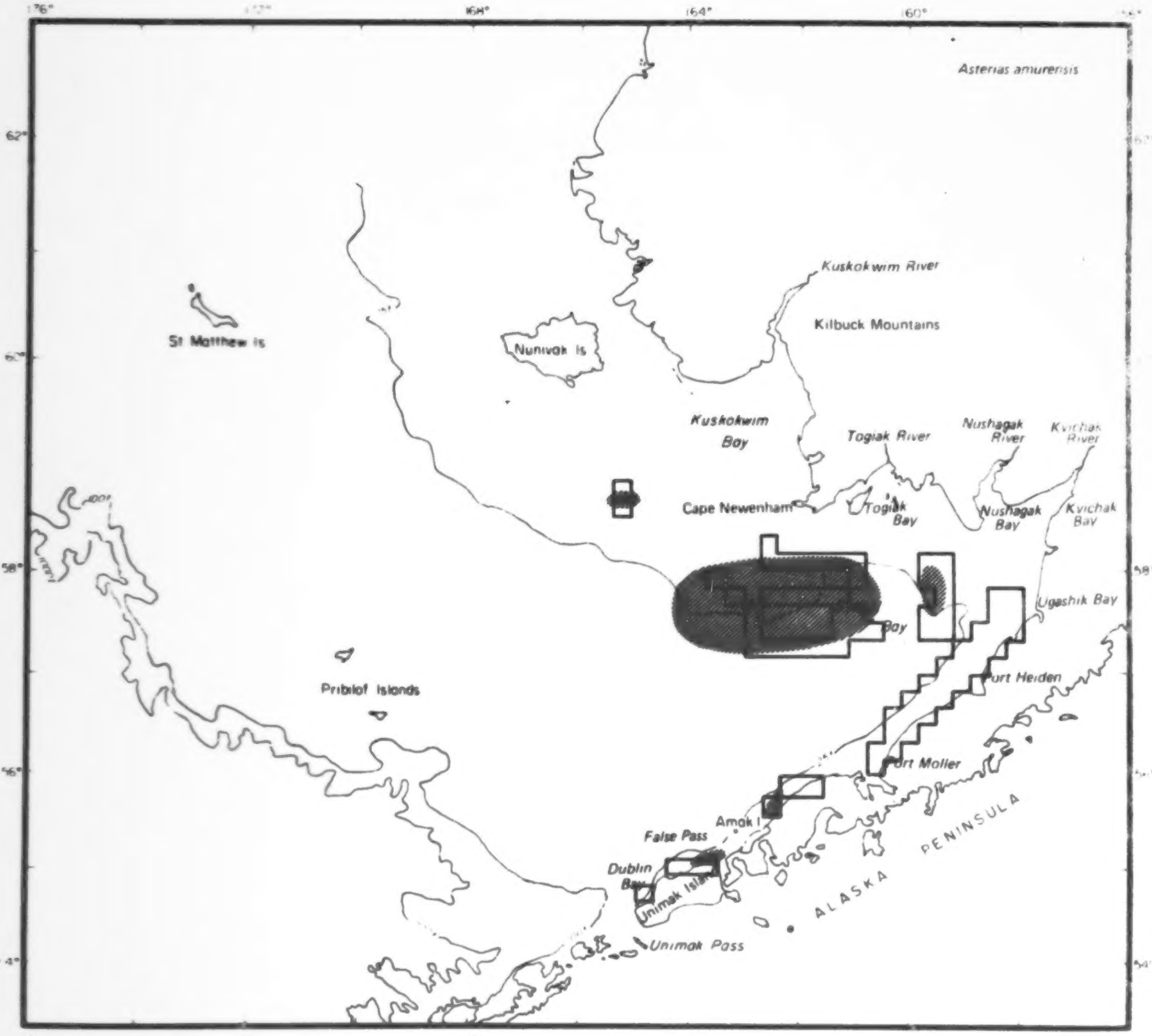

176°
172°
168°
164°
160°
62°
60°
58°
56°
54°
Asterias amurensis
St Matthew Is
Nunivak Is
Kuskokwim River
Kilbuck Mountains
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.15. The distribution of the sea star, *Asterias amurensis*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The sea star distribution is shown by oblique-lined patterns within the enclosure.

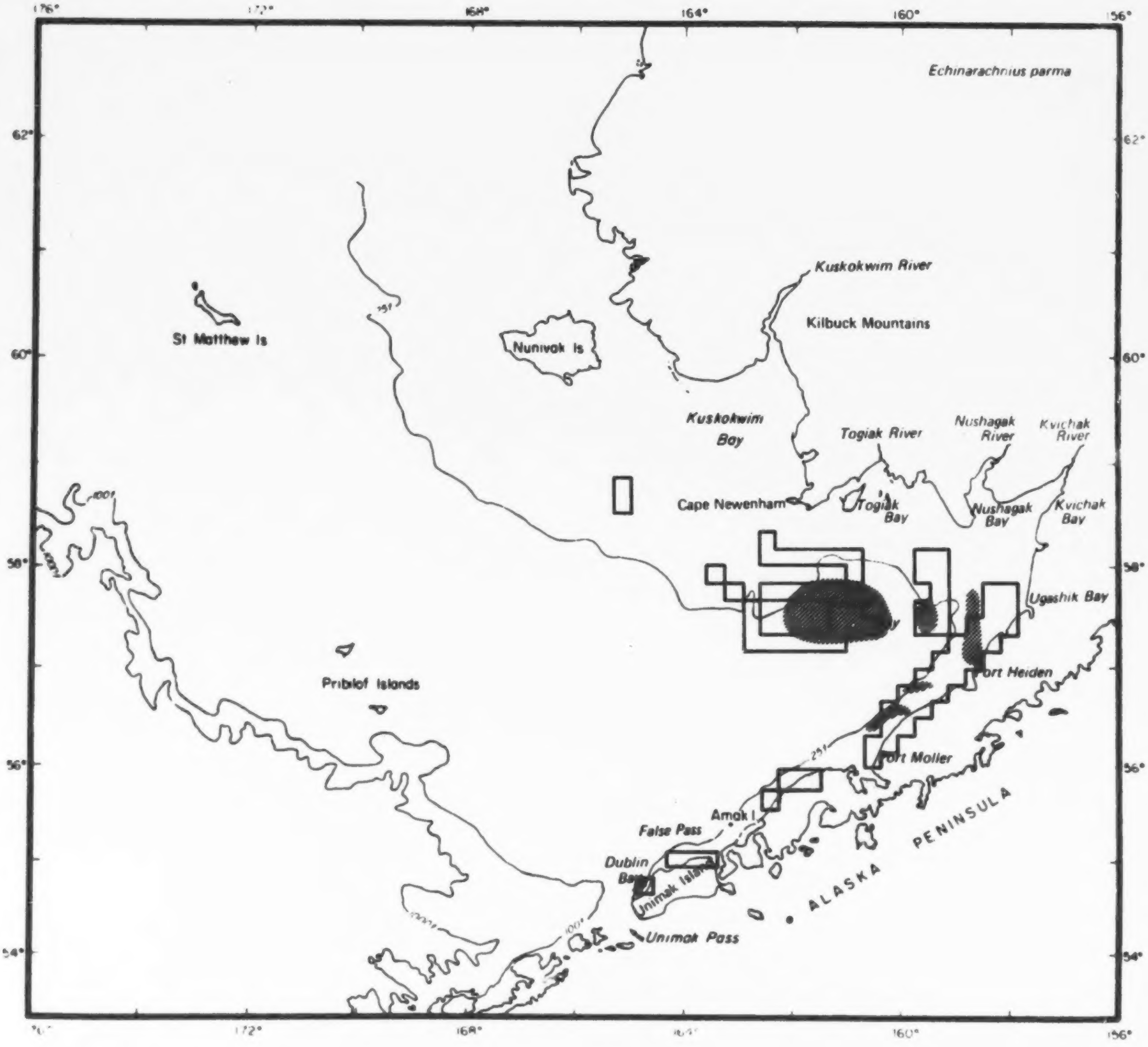

Echinarachnius parma
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
25f
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Ugashik Bay
Port Heiden
100f
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.16. The distribution of the sand dollar, *Echinarachnius parma*, taken by hydraulic dredge. Locations of regions where clam resource assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The sand dollar distribution is shown by oblique-lined patterns within the enclosure.

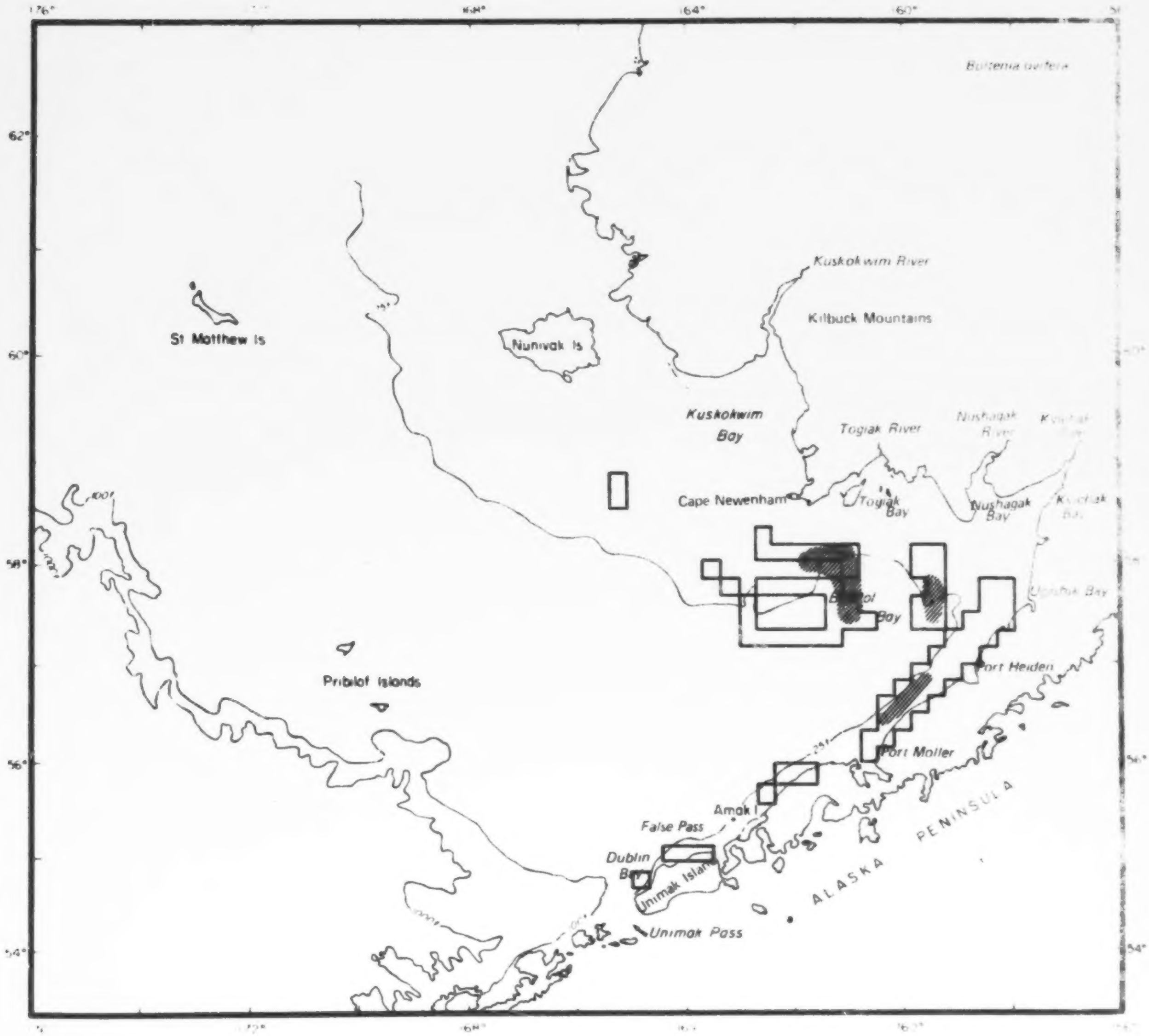

176°
168°
164°
160°
Boltenia ovifera
62°
60°
58°
56°
54°
St Matthew Is
Nunivak Is
Kuskokwim River
Kilbuck Mountains
Kuskokwim Bay
Togiak River
Nushagak River
Cape Newenham
Togiak Bay
Nushagak Bay
Bristol Bay
Pribilof Islands
Port Heiden
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.17. The distribution of the sea squirt or tunicate, *Boltenia ovifera*, taken by hydraulic dredge. Locations of regions where clam resources assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The sea squirt distribution is shown by oblique-lined patterns within the enclosure.

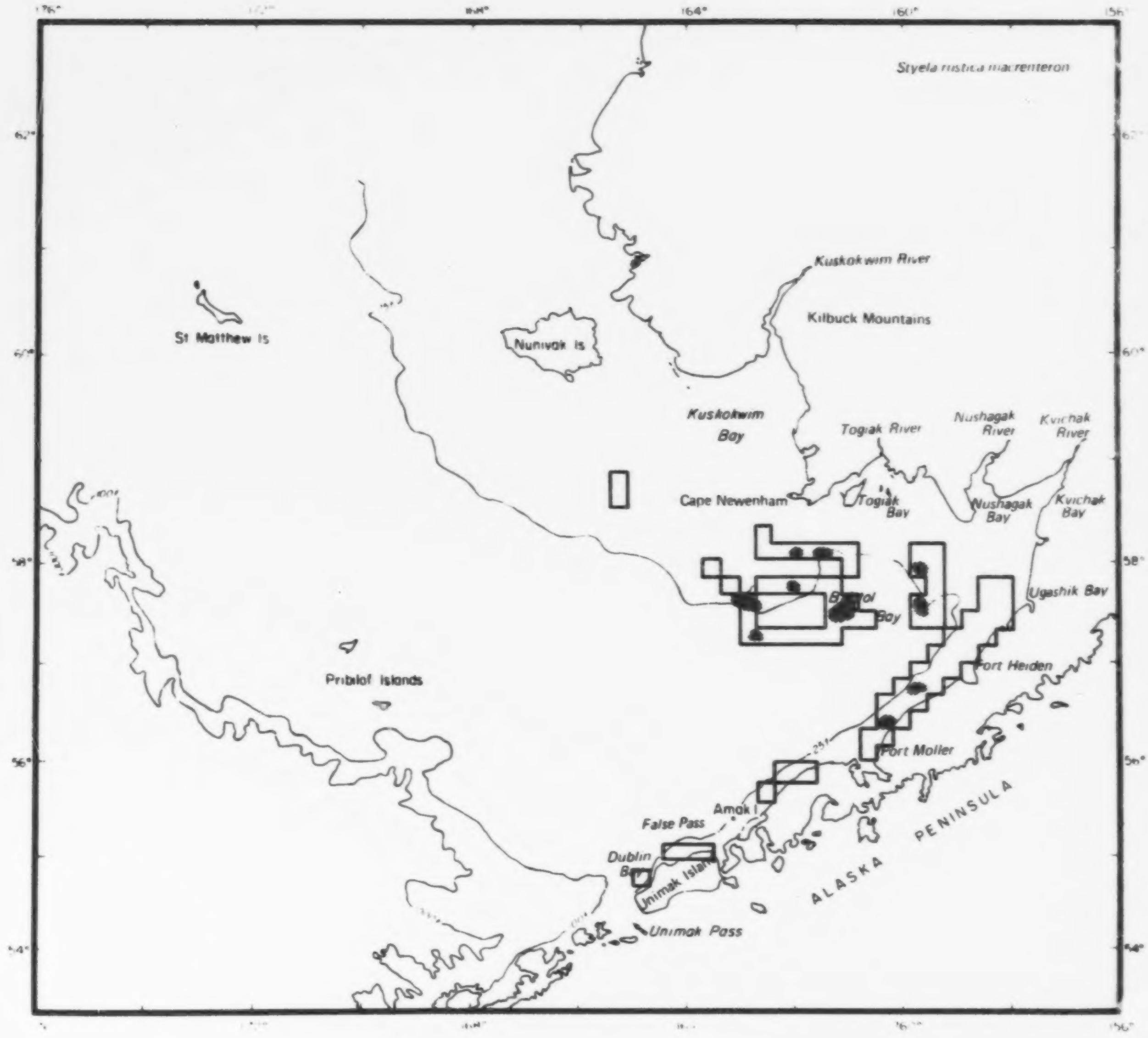

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
Styela rustica macrenteron
Kuskokwim River
Kilbuck Mountains
St Matthew Is
Nunivak Is
Kuskokwim Bay
Togiak River
Nushagak River
Kvichak River
Cape Newenham
Togiak Bay
Nushagak Bay
Kvichak Bay
Bristol Bay
Ugashik Bay
Port Heiden
Pribilof Islands
Port Moller
Amak I
False Pass
Dublin Bay
Unimak Island
Unimak Pass
ALASKA PENINSULA

Figure 4.18. The distribution of the sea squirt or tunicate, *Styela rustica macrenteron*, taken by hydraulic dredge. Locations of regions where clam resources assessment by the National Marine Fisheries Service was conducted are shown as irregular enclosures on the map. The sea squirt distribution is shown by oblique-lined patterns within the enclosure.

BEST DOCUMENT AVAILABLE

that most of the infaunal species of the southeastern Bering Sea have a broad depth range (Sections 1, 2, and 3).

The nearshore and mid-shelf infaunal species of the southeastern Bering Sea reported in this section exhibit a patchy distribution similar to that described by Haflinger (1978) for samples collected by van Veen grab in the southeastern Bering Sea (Section 1) and Stoker (1973, 1978) for the eastern Bering and Chukchi Sea shelves. A similar patchy distribution of epifauna is reported for the southeastern Bering Sea (Feder and Jewett, in press), and the northeastern Bering and southeastern Chukchi Sea (Feder and Jewett, 1978).

The large number of bivalves (*Spisula, Tellina, Macoma, Serripes, Mya*) of various older age classes located nearshore along the Alaska Peninsula (Hoberg, unpub. OCSEAP data) is a possible indication of decreased predation as compared to that occurring in northern nearshore and mid-shelf areas where numerous empty valves were observed (Feder and Jewett, 1978; Feder *et al.*, 1978b). No data are currently available on predator-prey interactions involving the above species in the nearshore region of Bristol Bay.

VIII. CONCLUSION

Invertebrates from the southeastern Bering shelf (Bristol Bay) exhibit patchy distributions and abundance, similar to the northeastern Bering Sea and southeastern Chukchi Sea.

No apparent difference in species numbers and biomass for the cobble and boulders underlying the sand-gravel substrate located in the outwash areas of the bays when compared to the coarse-medium sands located between the latter areas and the mid-shelf.

The polychaetes were associated with coarse-medium sands at 18-47 m, while the pelecypods occurred in coarse-medium sands at 18-55 m depths. The gastropods were associated with medium-fine sands at 18-47 m, while the echinoderms occurred in coarse-medium sand at 18-47 m depths. The tunicates were associated with coarse-medium sands at 18-47 m depths.

The sampling procedures used in previous OCSEAP studies - van Veen grab, pipe dredge, and trawl - were adequate to determine the distribution of the major portion of the species on the southeastern Bering Sea shelf.

APPENDIX 4.A

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

STATION NAME	TOW NUMBER	NUMBER OF INVERTEBRATE SPECIES	GRAMS PER METER SQUARED
I111	1	3	0.
I111	2	10	0.
I111	3	10	2.0980
I111	4	9	1.2250
I114	6	9	0.8588
I101	7	9	2.0408
I104	8	10	0.4798
I091	9	7	2.3140
J091	10	5	1.4276
K092	11	7	8.0600
J104	12	4	1.4528
J101	13	18	4.9594
J114	14	6	0.1578
J111	15	2	1.3720
J124	16	20	9.6054
J123	17	6	8.6892
H152	18	7	3.3080
G151	19	6	11.9680
G154	20	7	57.0008
G153	21	13	0.
F143	24	17	23.9209
F132	26	7	10.8318
E131	27	5	40.9839
E134	28	6	9.5853
E133	29	9	9.8072
E122	30	10	14.5936
E131	31	7	1.7477
F132	35	6	48.1900
F132	36	8	18.7317
F131	37	9	22.4318
F144	38	13	29.0823
G142	39	12	35.2124
G142	40	11	62.7276
G141	41	7	18.9382
H153	42	21	67.2166
H151	43	24	30.5388
I164	44	15	37.3502
I163	45	8	19.8312
I162	46	13	40.2334
I164	47	6	20.1136
I161	48	7	11.2342

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

STATION NAME	TOW NUMBER	NUMBER OF INVERTEBRATE SPECIES	GRAMS PER METER SQUARED
I161	49	2	5.4000
J142	50	3	22.5236
J141	51	8	26.8241
J144	52	12	24.0188
J143	53	4	10.3000
I141	54	12	13.0438
I143	55	10	22.6596
I142	56	23	19.3796
H141	57	15	17.7861
H143	58	12	14.2024
H121	59	22	7.8696
H124	60	15	2.4303
I123	61	8	0.8656
I112	62	14	1.5636
H111	63	12	6.3346
H111	64	17	10.0715
H112	65	10	1.5444
H113	66	5	0.7636
H102	67	4	0.1694
H103	68	3	2.7911
H092	69	5	16.7771
H093	70	6	8.9309
H094	71	13	5.2318
I093	72	10	3.4505
I081	73	12	9.8770
J083	74	13	7.0825
L053	75	10	8.0716
L054	76	3	1.4606
0BB1	77	4	8.5606
0BB2	78	6	2.9696
0KB1	79	5	1.2482
0KB2	80	2	1.7025
0KB3	81	5	1.7620
0KB4	82	2	0.5800
0DB1	83	2	0.5640
0DB2	84	3	1.4260
0DB2	85	1	0.0920
0DB4	86	3	0.1640
0DB4	87	1	4.0880
0DB7	88	3	1.1600
0DB8	90	2	0.

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

STATION NAME	TOW NUMBER	NUMBER OF INVERTEBRATE SPECIES	GRAMS PER METER SQUARED
0DB9	91	2	3.8160
0NC1	92	4	1.4301
0SL1	98	3	29.3823
C093	99	4	36.0552
C093	101	11	19.0876
C092	102	12	26.9484
F132	103	7	0.3576
F132	105	5	7.1800
F132	106	8	8.6600
F132	107	2	39.9900
F132	108	4	37.6636
F132	109	6	5.7258
F132	110	3	7.7192
F132	111	1	35.7500
F132	112	3	17.1536
F132	113	3	11.4347
F132	114	4	1.3126
F132	115	5	28.1640
F132	116	3	9.6038
F132	117	7	6.7675
F132	118	4	7.9880
F144	119	7	11.2400
F144	120	5	5.8252
F144	121	10	23.9036
F144	122	9	11.4172
F144	123	13	20.1783
F144	124	6	22.2940
F144	125	5	7.6201
F132	126	4	5.8274
F144	127	6	7.2559
F144	128	8	5.9500
F144	129	12	11.5592
F144	130	7	9.7092
F144	131	7	28.9638
F144	133	4	22.3376
G142	134	4	28.3320
E131	135	7	3.8900
E131	137	10	29.8063
E131	138	3	19.6400
E131	139	6	12.3636
E131	140	6	29.9216

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

STATION NAME	TOW NUMBER	NUMBER OF INVERTEBRATE SPECIES	GRAMS PER METER SQUARED
E131	141	1	7.3560
E131	142	3	71.0196
E134	144	3	13.4960
E134	145	5	22.5436
E134	146	2	11.4400
E134	147	6	20.9482
E134	148	3	11.3860
E134	149	8	14.3632
E134	150	5	13.3648
E134	151	1	13.0859
E134	152	1	10.8960
E134	153	3	10.9093
E134	154	5	16.0492
E134	155	2	11.6464
E134	156	3	4.5760
E134	158	6	5.1048
E134	159	1	18.1600
E132	160	2	24.1528
F132	161	2	15.9808
F143	162	4	71.5504
F143	163	6	42.5164
F144	164	5	3.5524
F144	165	9	5.9624
F144	166	5	34.9660
F144	167	10	36.6196
F144	168	7	21.7584
F144	169	6	38.9504
F144	170	4	35.0551
F144	171	10	45.6728
F144	172	6	14.7237
G151	173	9	20.9984
G151	175	4	23.3900
G151	176	8	37.5280
G151	177	7	67.4624
H152	178	2	19.3056
H152	180	5	18.2100
H152	181	2	9.4043
H152	182	3	15.2356
H152	183	3	21.9732
H152	184	3	23.6988
H152	185	5	16.6180

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

STATION NAME	TOW NUMBER	NUMBER OF INVERTEBRATE SPECIES	GRAMS PER METER SQUARED
H152	186	1	7.2640
H152	187	7	9.9088
H163	188	4	11.6424
H152	189	6	18.9744
H152	190	6	18.5676
H152	191	5	21.3940
H152	192	9	25.9060
H151	193	9	38.6940
H151	194	6	40.9880
F144	195	7	40.8544
F144	196	5	96.0149
F144	197	2	56.5419
F144	198	3	21.0971
F144	199	2	0.
F144	200	5	83.5832
F144	201	4	31.5256
H164	202	2	37.2840
H164	203	5	20.5659
H164	205	1	54.7471
H164	206	6	49.0600
H164	207	5	38.0824
H164	208	7	43.2906
H164	209	1	37.0464
H164	210	6	19.9282
H164	211	11	16.4904
H164	212	6	11.2220
H164	213	7	13.3876
H164	214	8	19.8484
H164	215	1	30.8720
H164	216	1	15.3452
H164	217	1	33.2933
H164	218	2	22.3368
H164	219	1	27.5124
H164	220	1	49.5768
H164	221	1	25.7872
H164	222	6	41.9160
H164	223	6	34.3724
G151	224	6	36.3168
G151	225	6	46.4827
G151	226	1	31.9616
	227	6	54.3904

DISTRIBUTION AND ABUNDANCE OF MARINE INVERTEBRATES COLLECTED BY CLAM DREDGE

STATION NAME	TOW NUMBER	NUMBER OF INVERTEBRATE SPECIES	GRAMS PER METER SQUARED
G151	228	5	39.9785
G151	229	3	26.1528

BEST DOCUMENT AVAILABLE

APPENDIX 4.B

GROWTH AND SIZE OF THE PINKNECK CLAM, *SPISULA POLYNYMA*, IN THE EASTERN BERING SEA*

H. M. Feder, A. J. Paul and J. M. Paul

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

and

J. R. Zweifel

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center
La Jolla, California 92038

---

*Unpublished manuscript.

ABSTRACT

Specimens of *Spisula polynyma* were collected in the summer of 1977 from three stations in the eastern Bering Sea for the study of growth, size and age at sexual maturity. The preponderance of older clams in the samples (77% $\geq$ age 9) was due to gear bias; 12 year olds were the first year class to be fully retained by the dredge.

The aging technique utilized was the annular method. The largest clam was 135 mm long at 14 years of age. The oldest clams were 16 years. Direct estimates of annual increase in shell length were typically 7 to 16 mm.

The Gompertz growth equation was used to express the increase of shell length with age. Clams from Stations H-15-2 and Dublin Bay had similar growth rates while those from F-13-2 averaged 3 to 9 mm larger for the same age. Average size at age estimated from the Gompertz equation was essentially indistinguishable from the direct estimates. The model equations indicate an increase in growth rates until about 52 mm and a continuing decline thereafter.

Growth histories of 15 years classes were determined by measuring the length of every annulus. The mean lengths of annuli 1 through 4 ranged from 1 to 5 mm while variations in mean lengths of annuli 5 through 11 ranged from 5 through 10 mm.

Gonads were examined histologically. The 7-year-old clams, 69 mm mean length, were the first year class where the majority of individuals were sexually mature. All older and larger clams had well developed gonads.

ACKNOWLEDGMENTS

This project was conducted with funds provided by the University of Alaska Sea Grant Program and OCSEAP. We thank the following University of Alaska personnel: Max Hoberg for collection of clams; Judy McDonald and Phyllis Shoemaker for technical assistance. Lorraine Prescott, NMFS, La Jolla, completed the final draft.

INTRODUCTION

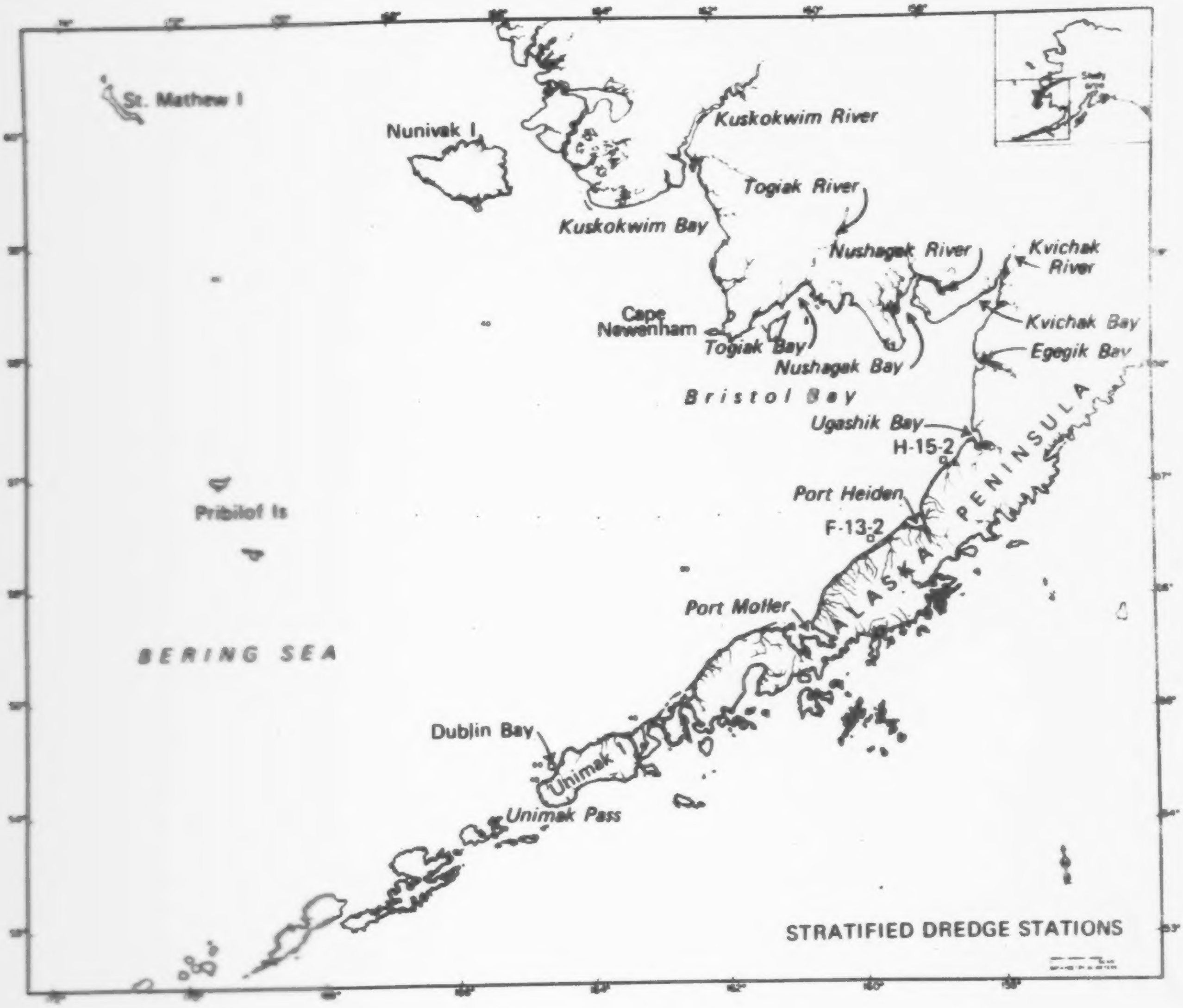
The pinkneck clam, *Spisula polynyma*, is a large bivalve found in intertidal and subtidal Alaskan waters. The extent of this resource is unknown; however, a cooperative survey by the National Marine Fisheries Service, University of Alaska, Alaska Department of Fish and Game and private interests have located populations with commercial potential in the eastern Bering Sea. Previous literature on *S. polynyma* is restricted to a geographic study by Chamberlin and Stearns (1963) and a report on growth and size-weight relationships of intertidal pinknecks in Prince William Sound (Feder *et al.*, 1976). Growth data are also available for subtidal Cook Inlet pinkneck clams (Feder *et al.*, 1978). No published work is available on the biology of subtidal Bering Sea pinkneck clams. The major objectives of this investigation were to provide information on growth rates, growth history, and size and age at maturity for pinkneck clams from the eastern Bering Sea.

METHODS

Specimens were collected in July and August 1977 from the F/V *Smaragd* with a modified east coast hydraulic clam dredge. The diameter of the rings in the retaining bag was 75 mm (3 in). Specimens from three stations (H-15-2: 57°10'N, 158°51'W; F-13-2: 56°36'N, 159°56'W; Dublin Bay: 54°42'N, 164°43'W) with large numbers of pinknecks were selected for study (Fig. 4B.1). The shell lengths of 652 clams were collected for aging. Age was determined by counting annuli, a series of closely spaced concentric growth lines that are the result of reduced shell growth in late summer and winter (see Paul and Feder, 1973 for discussion).

Since annuli were not validated in the field for *S. polynyma*, the technique of Hubbs and Hubbs (1953) was used to compare lengths of clams at each age. A significant difference ($\alpha = 0.05$) is demonstrated by this technique when the standard errors of the means of two comparable values fail to overlap.

A growth history was determined for all aged clams by measuring the shell length to the nearest millimeter at each annulus. Shell width, the


St. Mathew I
Nunivak I
Kuskokwim River
Togiak River
Kuskokwim Bay
Nushagak River
Kvichak River
Cape Newenham
Kvichak Bay
Egegik Bay
Togiak Bay
Nushagak Bay
Bristol Bay
Ugashik Bay
H-15-2
Port Heiden
F-13-2
ALASKA PENINSULA
Pribilof Is
Port Moller
BERING SEA
Dublin Bay
Unimak I
Unimak Pass
STRATIFIED DREDGE STATIONS

Appendix Figure 4B.1. Map of sampling area showing Stations H-15-2, F-13-2, and Dublin Bay.

distance from the umbo to the closest point to the margin, was measured to determine which age classes were fully retained by the mesh of the dredge.

The Gompertz growth equation was used to express the relationship of shell length with age. Total shell length, as opposed to annular length, was used in the equation. The model equation is most simply defined as the simultaneous solution of the equations $dL/dt = \gamma L$ and $d\ \gamma/dt = \alpha\gamma$ which states that in short time intervals, growth is exponential with an exponential decrease in the instantaneous growth rate with time. The direct solution results in the equation

$$L_t = L_o e^{A_o/\alpha(1-e^{-\alpha t})} \qquad (1)$$

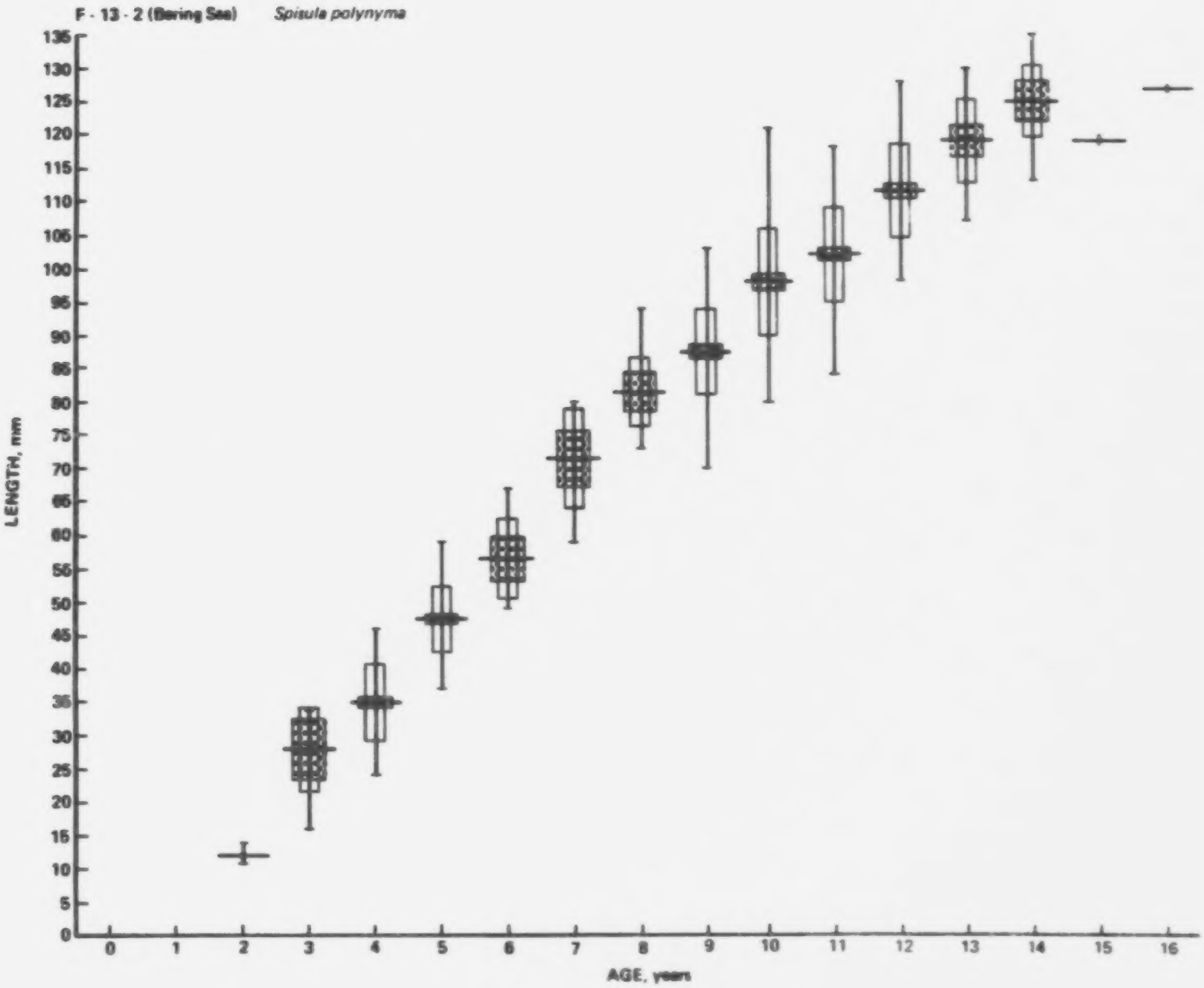
where L_t is length at time t, L_o is the length at t = o, A_o is the specific growth rate at t = o, and α is the rate of exponential decay, i.e., $A_t = A_o \exp(-\alpha t)$. The limiting or asymptotic size is $M = L_o\ e^{A_o/\alpha}$. We used the fitting procedure of Conway *et al.* (1970) as described in Zweifel and Lasker (1976). Estimated values were corrected by the factor $\exp(\hat{\sigma}^2/2)$ where $\hat{\sigma}^2$ is the estimated variance on the logarithmic scale.

Historical examination of the gonads of 70 clams was made to determine size at maturity. The gonadal mass of each clam was removed and preserved in 10% formalin. A cube of preserved gonadal tissue was removed from the mid-lateral portion of the visceral mass for preparation of slides. The tissue was dehydrated in alcohol, cleared in xylene, embedded in paraffin, sectioned at 10, 20 and 30 microns, and stained with Ehrlich's hematoxylin (Davenport, 1960).

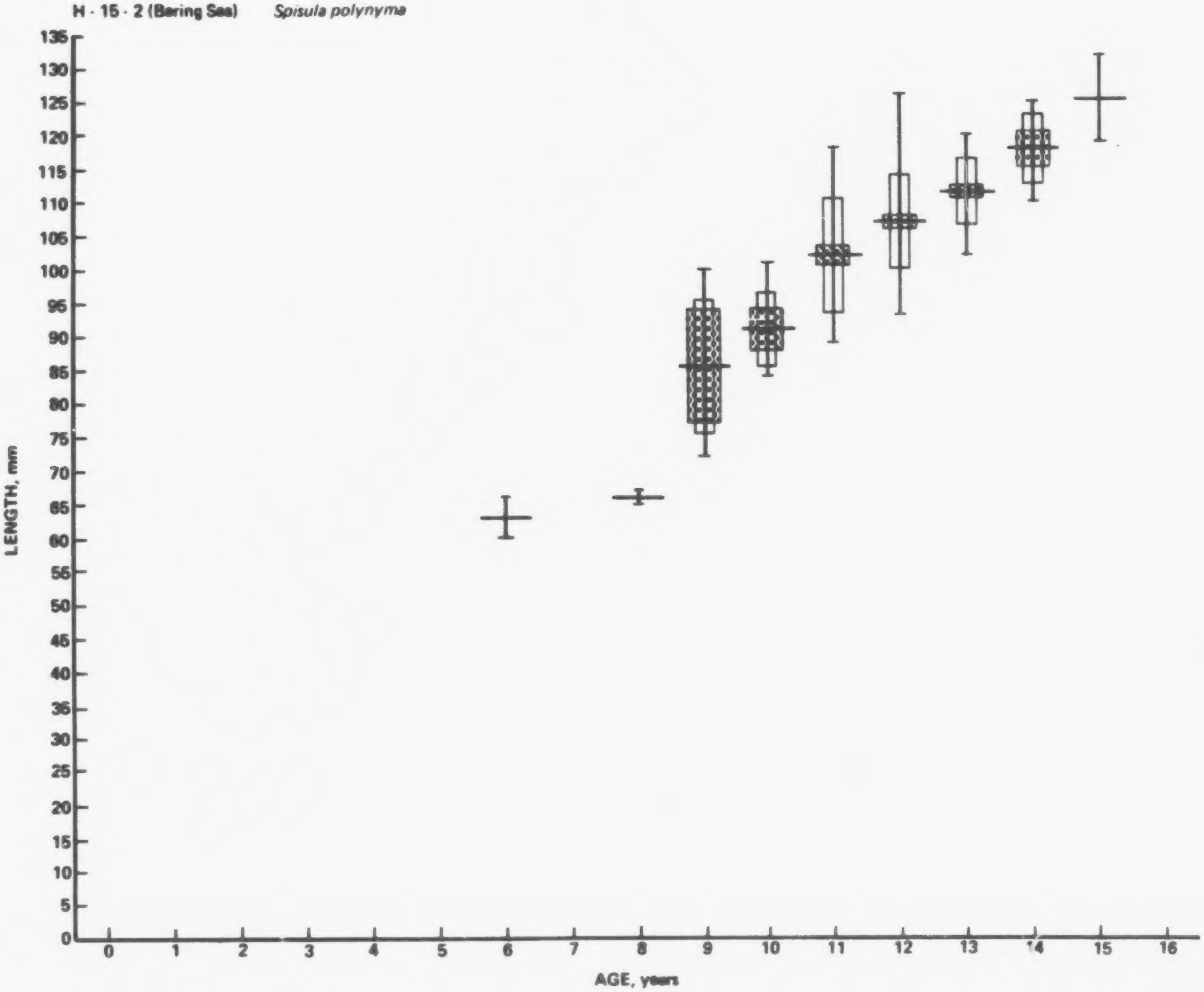
RESULTS AND DISCUSSION

Aging

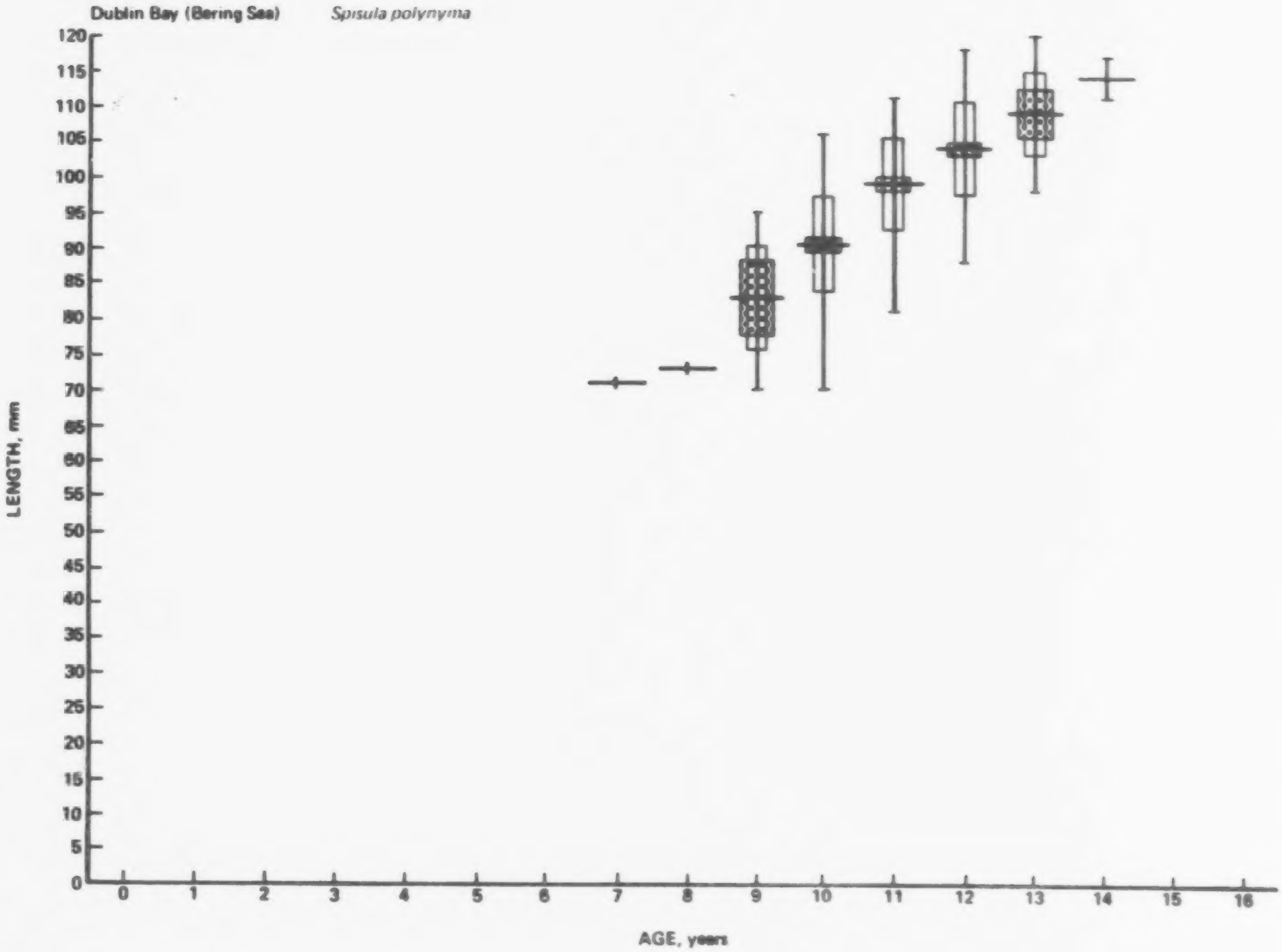
Annuli were generally distinct. The graphical method of Hubbs and Hubbs (1953) illustrates the integrity of the age classes with the failure of any of the standard error of the mean to overlap even when sample sizes are small (Figs. 4B.2-4).



Appendix Figure 4B.2. Growth curve for clams from Station F-13-2. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.



Appendix Figure 4B.3. Growth curve for clams from Station F-15-2. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.



Appendix Figure 4B.4. Growth curve for clams from Station Dublin Bay. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

The annular method of aging is reliable for Alaskan clams because of a strong seasonality of growth. All hard shell Alaska clams in which annular formation has been studied form a single annulus following the summer growth period (Weymouth *et al.*, 1931; Weymouth and Thompson, 1931; Quayle and Bourne, 1972; Paul and Feder, 1973). Therefore, it is reasonable to assume that pinkneck clams form a single annulus. However, following the growth of marked clams is the only method that will positively validate annulus formation and annual growth. This procedure was not possible in the present investigation, but should be encouraged in future studies.

The Gompertz growth equation was used to estimate total shell length as a function of age as determined from annular counts for each sampling location (Tables 4B.I, 4B.II, 4B.III). Utilization of total shell length, rather than length at the last annulus, resulted in an overestimation of length at age by approximately 3/4 of a year at Station H-15-2. At the other two stations, the overestimation was exactly one year indicating that sampling occurred just prior to the laying down of a new annulus.

Otherwise, no systematic departure from any of the curves was evident at any age. The parameter estimates for the growth equations in the three sampling areas are shown below where parameters are as defined in Equation (1).

	Location		
	H-15-2	DB	F-13-2
L_o	9.484	9.518	9.583
A_o	0.5410	0.5417	0.5669
α	0.1976	0.2010	0.2086
M	146.6	140.8	145.5
IP	53.97	51.81	53.39
$\hat{\sigma}$	0.1051	0.0628	0.0628

In the Gompertz equation, the inflection point (IP) i.c., the change from an increasing to a decreasing growth rate occurs at $t = \frac{1}{\alpha} \ln (A_o/\alpha)$, $y_t = L_o \exp \left(\frac{A_o}{\alpha} - 1\right)$ at approximately 52 mm for all three locations.

TABLE 4B.I

MEAN SHELL LENGTH FOR AGE CLASS OF *SPISULA POLYNYMA* FROM STATION F-13-2 IN THE SOUTHEASTERN BERING SEA, AND AN ANALYSIS OF VARIANCE OF SHELL LENGTHS FOR THE VARIOUS ANNULAR AGE CLASSES.

N = number of clams, OBS = observed, EST = estimated, MSL = mean shell length (mm), SD = standard deviation (mm), AI = annual increase in shell length (mm), R = range (mm).

Age	N	OBS MSL	EST. (t-.75)	SD	R	OBS AI	EST. (t-.5)
0	0	-	-	-	-	-	-
1	0	-	11.0	-	-	-	-
2	4	12.0	17.9	1.4	11-14	-	8.3
3	9	28.0	26.5	6.3	16-34	16.0	9.7
4	42	35.1	36.5	5.8	24-46	7.1	10.7
4	39	47.6	47.4	4.9	37-59	12.5	11.1
6	15	56.7	58.5	6.1	49-67	9.1	11.0
7	14	71.7	69.4	7.5	59-80	15.0	10.5
8	14	81.7	79.7	5.2	73-94	10.0	9.8
9	31	87.7	89.2	6.6	70-103	6.0	8.8
10	41	97.9	97.8	7.9	80-121	10.2	7.8
11	48	102.2	105.4	7.1	84-118	4.3	6.8
12	40	111.4	111.9	7.0	98-128	9.2	5.8
13	27	118.9	117.5	6.3	107-130	7.5	5.0
14	14	125.1	122.3	5.5	113-135	6.2	5.2
15	1	119.0	126.3	0	119	-	-
16	1	127.0	129.6	0	127	-	-
Total	340						

TABLE 4B.II

MEAN SHELL LENGTH FOR AGE CLASS OF *SPISULA POLYNYMA* FROM STATION F-15-2 IN THE SOUTHEASTERN BERING SEA, AND AN ANALYSIS OF VARIANCE OF SHELL LENGTHS FOR THE VARIOUS ANNULAR AGE CLASSES.

N = number of clams, OBS = observed, EST = estimated, MSL = mean shell length (mm), SD = standard deviation (mm), Al = annual increase in shell length (mm), R = range (mm).

Age	N	OBS MSL	EST. (t-.75)	SD	R	OBS Al	EST. (t-.5)
0	-	-	-	-	-	-	-
1	0	-	-	-	-	-	-
2	0	-	-	-	-	-	7.7
3	0	-	-	-	-	-	9.2
4	0	-	-	-	-	-	10.1
5	0	-	-	-	-	-	10.6
6	2	63.0	53.0	4.2	60-66	-	10.7
7	0	-	-	-	-	-	10.3
8	2	66.0	74.2	1.4	65.95	-	9.7
9	7	85.3	83.9	10.0	72.100	19.3	8.9
10	17	92.9	92.8	7.3	84-118	7.6	8.0
11	30	101.5	100.8	8.3	89-117	8.6	7.1
12	45	107.1	107.9	6.9	93-126	5.6	6.2
13	32	111.5	114.1	5.1	102-120	4.4	5.3
14	17	118.0	119.5	5.3	110-125	6.5	4.6
15	2	125.5	124.1	9.2	114-132	7.5	3.9
16	0	-	-	-	-	-	-
Total	154						

TABLE 4B.III

MEAN SHELL LENGTH FOR AGE CLASS OF *SPISULA POLYNYMA* FROM STATION DUBLIN BAY IN THE SOUTHEASTERN BERING SEA, AND AN ANALYSIS OF VARIANCE OF SHELL LENGTHS FOR THE VARIOUS ANNULAR AGE CLASSES.

N = number of clams, OBS = observed, EST = estimated, MSL = mean shell length (mm), SD = standard deviation (mm), Al = annual increase in shell length (mm), R = range (mm).

Age	N	OBS MSL	EST. (t-.75)	SD	R	OBS Al	EST. (t-.5)
0	0	-	-	-	-	-	-
1	0	-	-	-	-	-	-
2	0	-	-	-	-	-	7.7
3	0	-	-	-	-	-	9.1
4	0	-	-	-	-	-	10.0
5	0	-	-	-	-	-	10.4
6	0	-	-	-	-	-	10.4
7	1	71.0	63.0	0	71	-	10.0
8	1	73.0	73.0	0	73	2.0	9.3
9	9	83.3	82.3	7.3	70-91	10.3	8.5
10	37	90.9	90.8	6.7	70-106	7.6	7.6
11	49	98.8	98.4	6.4	81-111	7.9	6.7
12	36	104.3	105.1	6.6	88-118	5.5	5.8
13	12	109.3	110.9	5.9	98-116	5.0	5.0
14	2	114.0	115.9	4.2	111-117	4.7	4.2
15	0	-	-	-	-	-	-
16	0	-	-	-	-	-	-
Total	147						

The model equations may also be used to estimate the annual growth rates at each age. The relationship is $\frac{dL}{dt} = LA_o e^{-\alpha t}$.

In tables 4B.1-3, the estimated size at age and annual growth rates are shown for the three sampling locations, where growth rates are estimated at the mid-point of each interval.

Age and Growth

The majority (77%) of the 652 *Spisula polynyma* examined were 9 years of age or older. The oldest clam examined was 16 years of age and 127 mm in length. The largest clam was 14 years old and 135 mm long. The annual increase in shell length for all age classes was typically 7 to 16 mm. The mean shell lengths for clams from Stations F-13-2 were between 3 and 9 mm larger than those from Station H-15-2 and Dublin Bay (Tables 4B.1-3, Figs. 4B.2-4).

The observed annual increases in shell length as determined by measurement and those increases determined with the Gompertz equation are similar (Tables 4B.I, 4B.II, 4B.III). The Gompertz equation is useful for expressing growth in a variety of organisms and life stages (e.g., Zweifel and Lasker, 1976; Perrin *et al*, 1976). In many situations more than one growth cycle is evident which may be related to factors such as metamosphosis, sexual maturity or changes in behavior and environment. In *S. polynyma*, a single growth cycle was observed for the available age classes. The Gompertz curve is asymmetric around the inflection point at $L_o e(\frac{A_o}{\alpha} - 1)$, i.e., as measured from this point on the curve, equal increments and decrements of size do not correspond to equal intervals of time. This characteristic made the equation more useful than others, such as the logistic or simple von Bertalanffy, for expressing growth over the considerable range of age available for *S. polynyma*.

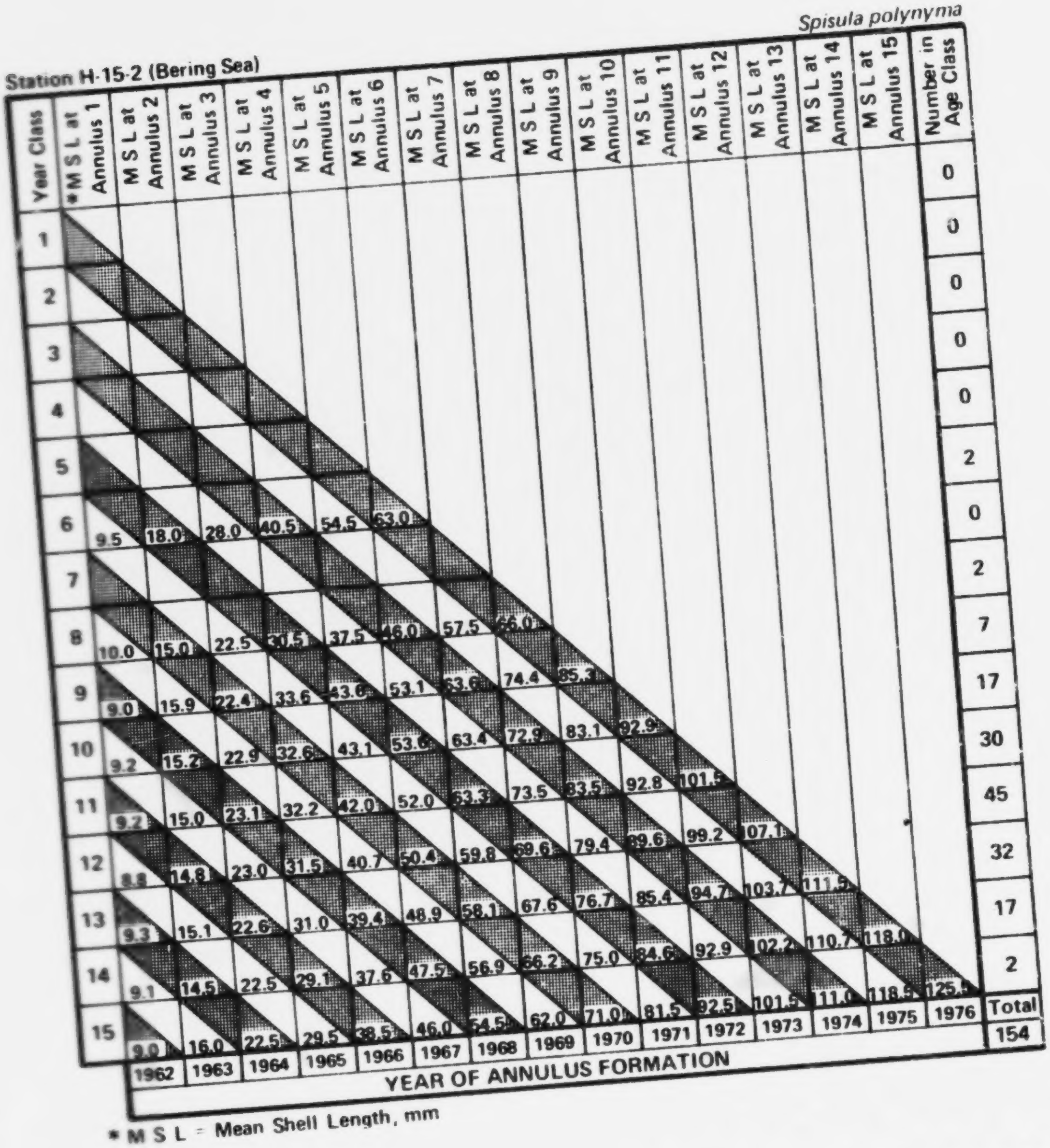
The vertical columns of the growth history tables (Figs. 4B.5-7) provide information on length at age of 14 or 15 years of growth. Examination of these lengths suggest that growth rates were variable over this period, although much of this variability may be due to small sample size. If comparisons of mean lengths are restricted to values represented by 10 or

Station F-13-2 (Bering Sea) *Spisula polynyma*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	M S L at Annulus 15	M S L at Annulus 16	Number in Age Class
1																	0
2	7.0	12.0															4
3	9.2	18.2	28.0														9
4	8.0	14.0	23.7	35.1													42
5	8.1	15.0	25.5	36.1	47.6												39
6	7.9	14.8	23.3	35.0	46.1	56.7											15
7	8.5	16.1	25.6	37.8	49.9	60.4	71.7										14
8	8.6	15.7	24.4	34.9	46.9	58.8	70.7	81.7									14
9	9.3	14.6	24.1	34.5	46.0	57.9	68.5	78.7	87.7								31
10	9.2	14.5	22.8	32.8	44.0	55.2	66.7	77.5	87.8	97.9							41
11	9.4	14.8	23.2	31.8	41.8	51.9	63.0	73.1	82.9	93.2	102.2						48
12	9.7	15.9	23.9	32.7	42.1	52.7	63.4	73.7	82.9	92.6	102.7	111.4					40
13	9.1	14.8	23.1	31.5	40.7	52.4	62.4	72.5	82.2	92.1	102.0	111.0	118.9				27
14	9.0	14.2	21.8	30.9	40.9	52.1	61.9	71.5	80.6	89.4	98.4	109.0	118.1	125.1			14
15	8.0	14.0	23.0	29.0	36.0	42.0	45.0	58.0	65.0	74.0	83.0	94.0	105.0	111.0	119.0		1
16	9.0	12.0	18.0	27.0	35.0	46.0	53.0	70.0	79.0	81.0	87.0	95.0	101.0	112.0	119.0	127.0	1
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION																340

* M S L = Mean Shell Length, mm

Appendix Figure 4B.5. Growth history for clams from Station F-13-2.



Appendix Figure 4B.6. Growth history for clams from Station H-15-2.

Station Dublin Bay (Bering Sea) *Spisula polynyma*

Year Class	* M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	M S L at Annulus 14	Number in Age Class
1															0
2															0
3															0
4															0
5															0
6															0
7	10.0	17.0	26.0	34.0	44.0	59.0	71.0								1
8	9.0	15.0	21.0	35.0	46.0	54.0	63.0	73.0							1
9	9.2	15.6	23.6	33.0	42.1	52.1	64.0	73.7	83.3						9
10	9.5	15.8	23.5	32.6	42.0	51.6	62.4	72.6	81.8	90.9					37
11	9.2	15.1	22.6	30.9	40.4	50.0	60.4	71.2	81.4	90.9	98.8				49
12	9.1	15.0	21.8	29.8	38.8	48.5	57.7	67.7	77.6	87.0	95.9	104.3			36
13	8.8	14.3	20.8	28.2	36.7	44.6	54.4	64.2	73.6	83.3	92.6	101.6	109.3		12
14	8.5	15.5	21.5	30.0	36.0	48.0	57.5	66.5	72.5	82.0	92.0	102.0	108.5	114.0	2
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Total
	YEAR OF ANNULUS FORMATION														147

* M S L = Mean Shell Length, mm

Appendix Figure 4B.7. Growth history for clams from Station Dublin Bay.

more measurements, a more dependable estimation of annual variation can be made. The age classes 10 through 14, 4 through 14 and 10 through 12 for Stations H-15-2, F-13-2 and Dublin Bay, respectively, all contain 10 or more individuals. Within these groups, the mean lengths of annuli 1 through 4 exhibited ranges of 2 to 5 mm while annuli 5 through 11 had variations ranging from 5 to 10 mm (Figs. 4B.5-7). These differences in lengths suggest that the conditions which affect growth vary on an annual basis.

Growth data are available for intertidal *S. polynyma* from Prince William Sound (Feder *et al.*, 1976) and subtidal specimens from Cook Inlet (Feder *et al.*, 1978). In both of these collections length values for ages 0 through 9 are based on small sample sizes or back-measured lengths, therefore, comparisons are restricted to clams older than age 9. Individuals in the year classes 9 through 12 from all three areas have similar lengths with less than 10 mm difference (Table 4B.IV). The lengths of pinkneck clams 13 through 15 years of age from the Bering Sea and Cook Inlet are similar while the Prince William Sound clams appear to grow somewhat faster.

Growth data are available for *S. solidissima*, a closely related Atlantic species (see Jones *et al.*, 1978, for recent review). This clam is generally harvested at a shell length of 127 mm (Yancey and Welch, 1968). The most northerly growth data for this species comes from Prince Edward Island, Canada, where terminal lengths and ages of *S. solidissima* are 127 mm and 11 years, respectively (Kerswill, 1944). This compares with 127 mm length and 16 years for *S. polynyma* in the Bering Sea. *Spisula solidissima* grows more rapidly in the southern portions of its range. For example, surf clams reach 127 mm in shell length in only four to seven growing seasons off New Jersey (Yancey and Welch, 1968; Jones *et al.*, 1978). Therefore, it is reasonable to assume that the slower growth rates reported for *S. polynyma* are due, in part, to the lower water temperatures of the Bering Sea.

Size and Age at Maturity

Clams used in this investigation were considered mature if they met the following criteria: Males - Alveoli filled with developing and mature

TABLE 4B.IV

MEAN SHELL LENGTH OF SUBTIDAL COOK INLET (Feder *et al.*, 1978) INTERTIDAL PRINCE WILLIAM SOUND (Feder *et al.*, 1976), AND SUBTIDAL BERING SEA *SPISULA POLYNYMA*.

MSL = mean shell length (mm), SD = standard deviation.

Age	Cook Inlet		Prince William Sound		Bering Sea[1]	
	MSL	SD	MSL	SD	MSL	SD
0	5	0	-	-	-	-
1	10	1.2	8	1.3	-	-
2	15	2.2	13	2.3	12	1.4
3	-	-	22	3.3	28	6.3
4	-	-	32	4.0	35	5.8
5	-	-	43	4.8	48	4.9
6	-	-	57	5.7	57	6.2
7	-	-	66	6.3	69	9.2
8	-	-	77	6.5	78	8.0
9	80	5.9	88	6.7	85	8.2
10	92	6.6	98	6.6	94	8.0
11	98	5.1	108	6.6	101	7.4
12	107	5.3	115	6.3	108	7.4
13	112	7.3	122	6.1	114	6.9
14	114	4.0	127	6.6	121	6.5
15	120	6.2	133	6.0	123	7.5
Total Number of Clams	553		298		652	

---

[1] Data from all three stations included in the present report.

spermatozoa or in a partially spawned condition; females - alveoli filled with large, similar-sized ova or in a partially spawned condition (see Bayne, 1976; Ropes, 1968; Ropes and Stickney, 1965 for discussions of bivalve reproductive biology).

Sex could not be determined in clams less than 5 years of age and mean shell length of 48 mm. In most of the 5-year-old clams, gonadal tissue was present, but obvious gametes were absent in 89% of the specimens examined (Table 4B.4B.V). In the sexually mature 6-year old clams, the amount of gonadal tissue producing gametes was relatively small in comparison to the size of the entire gonad. Thus, 6-year-old clams probably do not release significant amounts of gametes during spawning. Eighty-two percent of the 7-year-old clams, 69 mm shell length, were sexually mature, and appeared to be in a partially spawned or spent condition. All of the older clams examined, except a single 10-year-old, were sexually mature. The sex of the 10-year-old clam could not be determined.

Histological preparations for this study were made on a small sample from a single collection period. Therefore, results summarized here are preliminary, and further study, inclusive of seasonal sampling, should be encouraged.

TABLE 4B.V

AGE, SIZE, NUMBER AND PERCENT MATURITY OF BERING SEA *SPISULA POLYNYMA* EXAMINED HISTOLOGICALLY

Age	Mean Shell Length (mm)	Number of Clams	Percent Mature	Comments
2	12	1	0	No gonadal tissue present
3	28	3	0	No gonadal tissue present
4	35	6	0	Only one clam had gonadal tissue
5	48	18	11	Two mature clams partially spawned
6	57	15	40	Four mature clams partially spawned; one clam spent
7	69	11	82	Seven mature clams partially spawned; two clams spent
8	78	5	100	Four mature clams partially spawned; one clam spent
9	85	5	100	Four mature clams partially spawned; one clam spent
10	94	1	0	Sex undetermined
11	101	3	100	Three mature clams partially spawned
12	-	0	-	
13	114	2	100	Two clams spent

REFERENCES

Bayne, B. L. 1976. Marine mussels: Their ecology and physiology. Int. Biol. Prog. 10. Cambridge. 506 p.

Chamberlin, L. J. and F. Stearns. 1963. A geographic study of the clam, *Spisula polynyma* (Stimpson). Serial Atlas of the Marine Environment, Folio 3. Am. Geogr. Soc. 12 p.

Conway, G. R., N. R. Glass and J. C. Wilcox. 1970. Fitting nonlinear models to biological data by Marquardt's algorithms. *Ecology* 51:503-507.

Davenport, H. A. 1960. *Histological and histochemical technics.* W. B. Saunders Co., Philadelphia, 401 p.

Feder, H. M., A. J. Paul and J. M. Paul. 1976. Growth and size-weight relationship of the pinkneck clam, *Spisula polynyma*, in Hartney Bay, Prince William Sound, Alaska. Proc. Nat. Shellfish Assoc. 66:21-25.

Feder, H. M., S. C. Jewett, J. M. Paul and A. J. Paul. 1978. Distribution abundance, community structure and trophic relationships of the nearshore benthos of the Kodiak Shelf, Cook Inlet, northeast Gulf of Alaska and the Bering Sea. Annual Report to NOAA, R.U. No. 5. 315 p.

Hubbs, C. L. and C. Hubbs. 1953. An improved graphical analysis and comparison of series of samples. *Syst. Zool.* 2:49-56.

Jones, D. S., I. Thompson and W. Ambrose. 1978. Age and growth rate determinations for the Atlantic surf clam, *Spisula solidissima* (Bivalvia: Mactracea), based on internal growth lines in shell cross sections. *Mar. Biol.* 47:63-70.

Kerswill, C. J. 1944. The growth rate of bar clams. Fish. Res, Bd. Canada, Prog. Rep. Atl. Coast Sta. 35:18-20.

Paul, A. J. and H. M. Feder. 1973. Growth, recruitment, and distribution of the littleneck clam, *Protothaca staminea*, in Galena Bay, Prince William Sound, Alaska. *Fish. Bull., U.S.* 71(3):665-677.

Perrin, W. F., J. M. Coe and J. R. Zweifel. 1976. Growth and reproduction of the spotted porpoise, *Stenella attenuata*, in the offshore eastern tropical Pacific. *Fish. Bull., U.S.* 74(2):229-269.

Quayle, D. B. and N. Bourne. 1972. The clam fisheries of British Columbia. Bull. Fish. Res. Bd. Canada 179. 70 p.

Ropes, J. W. 1968. Reproductive cycle of the surf clam, *Spisula solidissima*, in offshore New Jersey. *Biol. Bull.* 135(2):349-365.

Ropes, J. W. and A. P. Stickney. 1965. Reproductive cycle of *Mya arenaria* in New England. *Biol. Bull.* 128(2):315-327.

Snedecor, G. W. 1956. *Statical methods applied to experiments in agriculture and biology.* 5th ed. Iowa State College Press, Ames. 534 p.

Weymouth, F. W. and S. H. Thompson. 1931. The age and growth of the Pacific cockle, *Cardium corbis*, Martyn. *Bull. Bur. Fish.* 46:633-641.

Weymouth, F. W., H. C. McMilland and W. H. Rich. 1931. Latitude and relative growth in the razor clam, *Siliqua patula.* *J. Exp. Biol.* 8: 228-249.

Yancey, R. M. and W. R. Welch. 1968. The Atlantic coast surf clam, with a partial bibliography. *Bur. Comm. Fish. Circ.*, 288. 13 p.

Zweifel, J. R. and R. Lasker. 1976. Prehatch and posthatch growth of fishes--a general model. *Fish. Bull. U.S.* 74(3):609-621.

SECTION 5

BIOLOGY OF SIX SELECTED SPECIES OF SUBTIDAL CLAMS FROM THE SOUTHEASTERN BERING SEA

ACKNOWLEDGEMENTS

We would like to thank the officers and crew of the NOAA Ship *Miller Freeman* for their aid in collecting samples. We would also like to thank the following Institute of Marine Science, University of Alaska personnel: Cydney Hansen, Rosemary Hobson, and Dave Nebert for assistance in data processing; Ana Lea Vincent, Helen Stockholm and the IMS Publications staff for aid in preparation of this report.

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objective of this study was to examine selected aspects of the biology of six species of subtidal clams (*Nucula tenuis, Nuculana fossa, Yoldia amygdalea, Spisula polynyma, Tellina lutea, Macoma calcarea*) from the southeastern Bering Sea shelf. Specifically, it was intended to (1) examine age and growth, (2) obtain preliminary information on recruitment, and (3) provide some preliminary information on mortality rates, for the six species of clams.

All species of bivalves examined exhibited variable recruitment success at individual stations. However, when the age composition of clams from all stations combined is considered, no cases of total year class failure for the study are observed. Data necessary to determine the causes for recruitment success and failure in the southeastern Bering Sea are not available.

The composition by age of all six species of clams at the stations sampled was often characterized by the occurrence of numerous older individuals. This contrast with clam data from lower Cook Inlet where younger individuals of *Nucula tenuis, Macoma calcarea* and *Spisula polynyma* always predominate. The large number of older individuals present in the Bering Sea suggests that predation may not be a major factor in bivalve mortality at all of the stations examined. Low temperatures preclude bottom fishes from feeding on the shelf year round, and may exclude them entirely from the shelf in cool years. However, stomach analyses of Bering Sea snow and king crabs collected in May indicate that these predators feed on bivalves on the shelf at least part of the year. In Cook Inlet, *N. tenuis* and *M. calcarea* are heavily preyed upon by the snow crab (*Chionoecetes bairdi*), the king crab (*Paralithodes camtschatica*), hermit crabs, shrimps (primarily crangonids), predatory gastropods, and flat fishes throughout the year. Further study is necessary to clarify predator-prey interactions occurring in the Bering Sea.

In the six species of Bering Sea clams studied, variable recruitment success at individual stations and non-random distributions make monitoring at specific stations impractical; however, use of pooled data from a number of stations in an area should prove useful.

Growth rates of the species examined, as evidenced by growth histories, have been relatively stable over time. Thus, growth and growth history analyses could be used to detect changes in the environment (as might occur following an oil spill), because pre-spill growth rates could be determined for the area by examining growth histories of clams collected after the stress had occurred.

II. INTRODUCTION

General Nature and Scope of Study

See general comments under this heading in Section 1.

It was the intent of the research described in this section to examine selected aspects of the biology of six species of subtidal clams (*Nucula tenuis, Nuculana fossa, Yoldia amygdalea, Spisula polynyma, Tellina lutea, Macoma calcarea*). Specifically, it was intended to examine age and growth, some aspects of recruitment, and mortality rates, for the six species of clams.

Relevance to Problems of Petroleum Development

See general comments under this heading in Section 1.

III. CURRENT STATE OF KNOWLEDGE

See general comments under this heading in Section 1.

Few data on non-commercially important invertebrate components of the benthos of the Bering Sea were available until recent Outer Continental Shelf Environmental Assessment Program (OCSEAP) studies were initiated. The primary data available were principally catch and assessment records for commercial shellfish species (Feder, 1977). Based on OCSEAP feeding studies accomplished in the Bering Sea, it is apparent that benthic invertebrates play an important role in the food dynamics of commercial crabs and demersal fishes there (Feder *et al.*, 1978c).

The distribution of bivalves on the southeastern Bering Sea shelf was incompletely known prior to investigations by OCSEAP. Past investigations of Bering Sea bivalves were centered primarily in the vicinity of the Gulf of Anadyr (see Feder, 1977 for literature review). More recent investigations of the infauna, including studies on bivalve molluscs (Rowland, 1973; Haflinger, 1978; Stoker, 1978) from the southeastern and northeastern Bering Sea, are available. The studies by Rowland (1973) and Stoker (1978) include discussions of the distribution of clams in relation to sediment parameters.

Subtidal bivalves are an important link in benthic food webs leading to snow crab, king crab, hermit crabs, some flat fishes, and other organisms in the Bering Sea. The population dynamics of Bering Sea clams are difficult to investigate because of their patchy distribution. However, yearly growth and growth history analyses provide promising techniques for detecting changes in the environment which may affect the growth rates of bivalves. The age structure of six species of subtidal clams from several Bering Sea stations is presented in this section. Age data provide information on recruitment and mortality rates. These data, in conjunction with stomach analysis, are useful in determining the importance of clams in food webs.

IV. STUDY AREA

See study area description under this heading in Sections 1 and 2.

All samples were collected on a grid established for the Outer Continental Shelf Environmental Assessment Program (OCSEAP) benthic infaunal program (Feder, 1976; Sections 1 and 2; Fig. 5.1).

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

See general comments under this heading in Sections 1 and 2.

The samples were collected in May 1976 with a pipe dredge (100 cm x 34 cm) by the NOAA Ship *Miller Freeman* on a grid established for the Outer Continental Shelf Environmental Assessment Program (OCSEAP) benthic infaunal program (Feder, 1976; Fig. 5.1). Sediments were washed through a 1 x 1 mm mesh screen, and clams were separated from other benthic organisms. Supplementary samples of *Spisula polynyma* were taken with a hydraulic clam dredge by the F/V *Smaragd* in July and August 1977 along the west side of the Alaska Peninsula, and these data are summarized in Appendix 4.B.

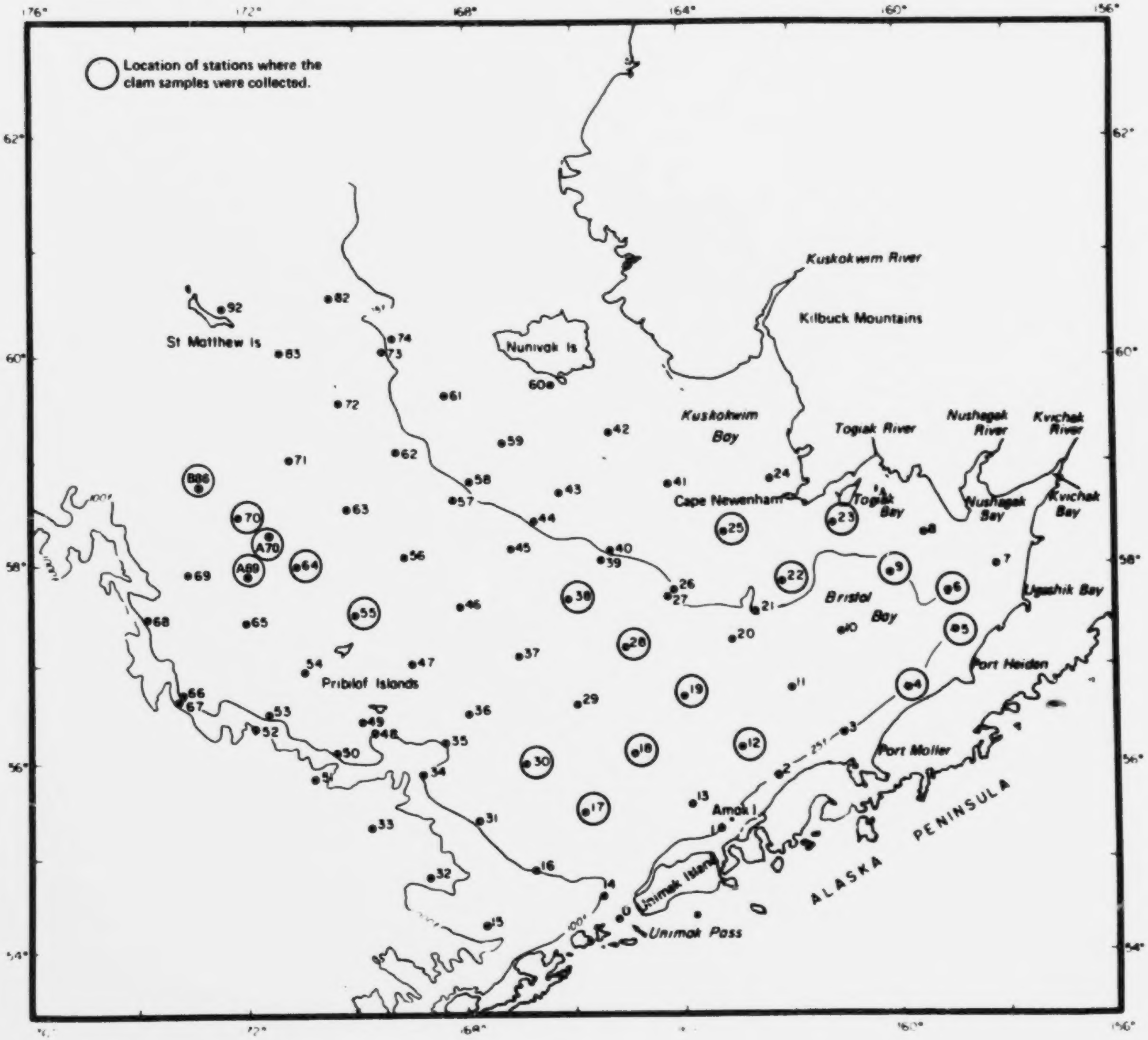

Location of stations where the clam samples were collected.
176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
St Matthew Is
Nunivak Is
Kuskokwim River
Kilbuck Mountains
Kuskokwim Bay
Cape Newenham
Togiak River
Togiak Bay
Nushagak River
Nushagak Bay
Kvichak River
Kvichak Bay
Ugashik Bay
Bristol Bay
Port Heiden
Port Moller
Pribilof Islands
Amak I
Unimak Island
Unimak Pass
ALASKA PENINSULA
100 f
25 f
92
82
83
74
73
72
71
61
60
62
59
42
41
24
B86
70
A70
A89
69
64
63
58
57
43
44
45
56
40
39
25
23
8
22
9
6
7
26
27
21
68
65
55
46
38
28
20
10
5
54
47
37
19
11
4
66
67
53
52
49
48
36
29
35
50
51
34
30
18
12
3
2
17
13
33
31
1
16
32
14
15
0

Figure 5.1. Location of stations where clam samples were collected.

Six common, relatively ubiquitous species were selected for detailed study (Table 5.I); *Nucula tenuis, Nuculana fossa, Yoldia amygdalea, Spisula polynyma, Tellina lutea,* and *Macoma calcarea.* All clams of these species that were collected were aged. *Clinocardium ciliatum* was common, but severe abrasion of the valves prevented accurate aging of the available material; this species is not included here. Specimens from only four stations where *M. calcarea* were abundant were aged. Aging was accomplished by the annular method (Weymouth, 1923) under a 2x lens and a Nikon dissection microscope. Annuli, a series of closely spaced concentric growth rings, are the result of slow growth at low winter temperatures (see Paul and Feder, 1973, for the criteria to determine true annuli). The term 0 age refers to individuals of the settling year class that have undergone only one growing season (5 to 6 months) before forming their first winter annulus. Thus, individuals referred to as 1 year of age are actually 17 or 18 months old, and have lived through two growing seasons. The 0 annulus was not measured, except on 0 age clams, because of abrasion on the umbo of most older shells. Two types of measurements were made on all clams: total shell length (mm) and length at each annulus (mm). Growth history tables were generated by the shell length at each annulus.

All data were processed by the Honeywell 66/40 computer. Mean shell length, range, standard deviation, and standard error of the mean for each clam species were plotted (when sample sizes exceeded five individuals) to examine the integrity of each age class (see Hubbs and Hubbs, 1953 for discussion of this graphical technique) and to compare growth rates for different stations.

Mortality rates were determined by the use of Gruffydd's technique (1974). The latter technique, developed to determine mortality in scallops, assumes that although recruitment varies from year to year at a particular station, overall recruitment to a large area is fairly constant. With this assumption, the total number of specimens available for *Nucula tenuis, Nuculana fossa,* and *Macoma calcarea* from all stations samples were plotted against age on semi-log paper. The sample sizes for the other three species were too small (< 150 individuals). The curves thus calculated eliminate the effect of uneven recruitment apparent in individual samples. Utilizing

TABLE 5.I

THE NUMBER OF SPECIMENS AGED FROM PIPE DREDGE COLLECTION IN THE BERING SEA, MAY 1976

Station	Latitude North	Longitude West	*Nucula tenuis*	*Nuculana fossa*	*Yoldia amygdalea*	*Spisula polynyma*	*Macoma calcarea*	*Tellina lutea*
4	56°46'	159°52'						3
5	57°21'	158°57'						37
6	57°40'	159°12'						5
9	57°55'	160°08'				13		
12	56°09'	162°57'	216					
17	55°20'	165°49'		3				
18	56°05'	164°53'	54	8				
19	56°40	163°57'	100					
22	57°49'	162°13'						8
23	58°20'	161°21'						15
25	58°19'	163°13'						3
28	57°10'	165°06'		55			183	
30	55°59'	166°53'	55	2				
38	57°39'	166°07'	27		12			
55	57°29'	169°59'				23		
64	58°00'	171°05'		121			236	
A69	57°58'	172°06'		10				
70	58°27'	172°07'	83	92	45		299	
A70	58°15'	171°34'		18	72		218	
B86	58°40'	173°07'		12				
		Totals	535	321	129	36	936	71

the number of individuals estimated from the curve rather than the actual catch, the percent mortality (Z) is estimated using the expression, $Z = \frac{N_t - N_{t+1}}{N_t}$; where N = number of clams and t = time. The mortality curves were drawn freehand. Aged clams were utilized to examine recruitment.

VI. RESULTS - DISCUSSION

Biology of Clams - Individual Species

See Section 2 for clam distribution maps, and data on clam distribution relative to sediment parameters and depth.

Nucula tenuis

A total of 535 *Nucula tenuis* from six stations (12, 18, 19, 30, 38, and 70) were aged (Tables 5.I, 5.II; Fig. 5.1). The graphical method of Hubbs and Hubbs (1953) illustrates the integrity of the age classes; none of the standard errors of the means overlap even when the sample sizes are small (Figs. 5.2-5.6). Annual recruitment success varied considerably at the six stations (Tables 5.III-5.VIII). For example, 89% of *N. tenuis* from Station 12 were in the 0 and 1 year classes, while 67% of the clams from Station 18 were between the ages of 4 and 6. Variable recruitment at individual stations has also been observed for *N. tenuis* in Cook Inlet (Feder, 1978).

The annual increase in shell length for each of the size classes in the Bering Sea stations examined was typically 0.4 to 1.8 mm. The oldest and largest *Nucula tenuis* collected was 9 years of age and 13.3 mm in length. Growth rates of *N. tenuis* from the six stations were similar, although a few small significant differences, $\alpha = 0.05$, do occur (Fig. 5.7).

From 1967 to 1975, the mean shell length at any given age for each station, as determined from the examinations of the growth histories of individual shells, showed some yearly variation (Figs. 5.8-5.12); however, 107 of the 121 mean annular lengths included in Figures 5.8-5.12 fall within the standard deviations calculated for each age class in the collection (Tables 5.II-5.VIII).

TABLE 5.II

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS*
FROM SIX STATIONS (12, 18, 19, 30, 38, and 70) IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation,
SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	102	1.4	0.2	0.02	1.1 - 1.8
1	121	2.2	0.3	0.03	1.7 - 2.9
2	79	3.5	0.4	0.04	2.7 - 4.2
3	84	4.8	0.4	0.05	3.8 - 5.8
4	45	6.0	0.4	0.07	5.0 - 6.9
5	27	7.2	0.5	0.21	6.3 - 8.9
6	30	8.5	0.7	0.25	7.4 - 9.8
7	31	10.0	0.7	0.12	8.5 - 11.4
8	11	10.5	0.5	0.32	10.0 - 11.3
9	5	12.3	0.7	0.68	11.6 - 13.3
Total =	535				

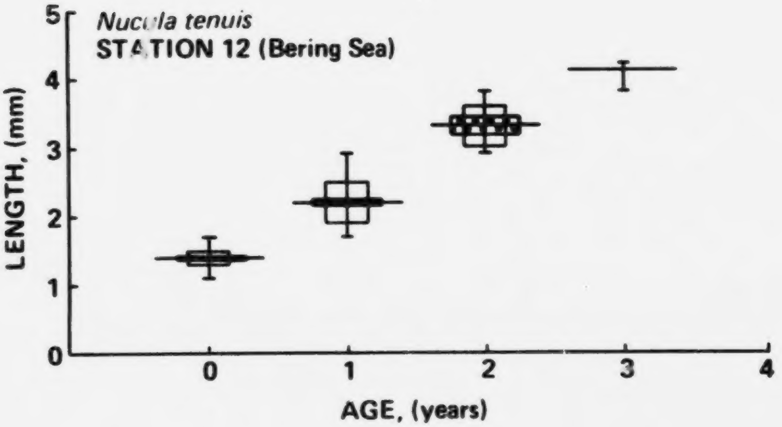


Figure 5.2. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 12 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

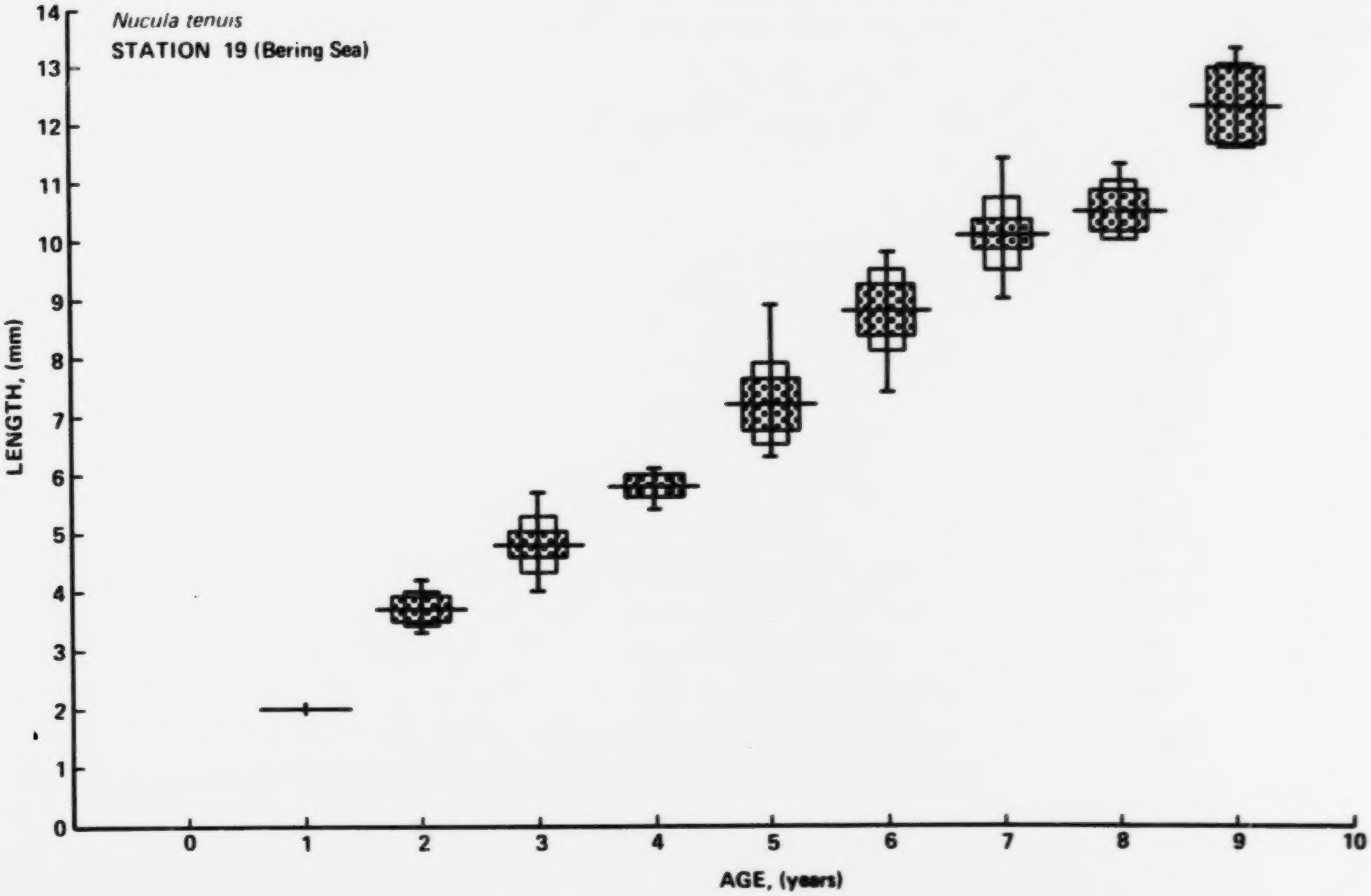


Figure 5.3. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 18 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

BEST DOCUMENT AVAILABLE

602

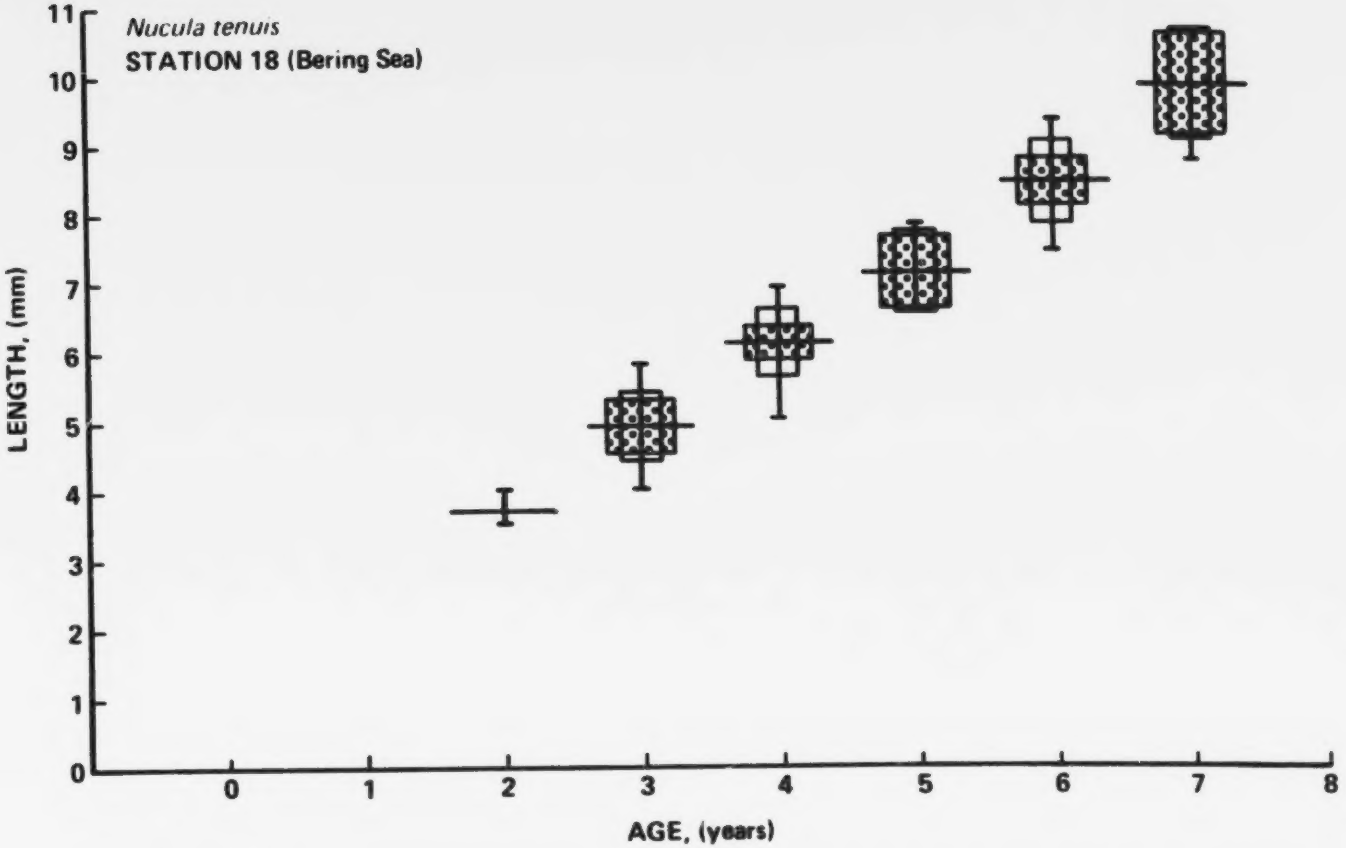


Figure 5.4. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 19 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

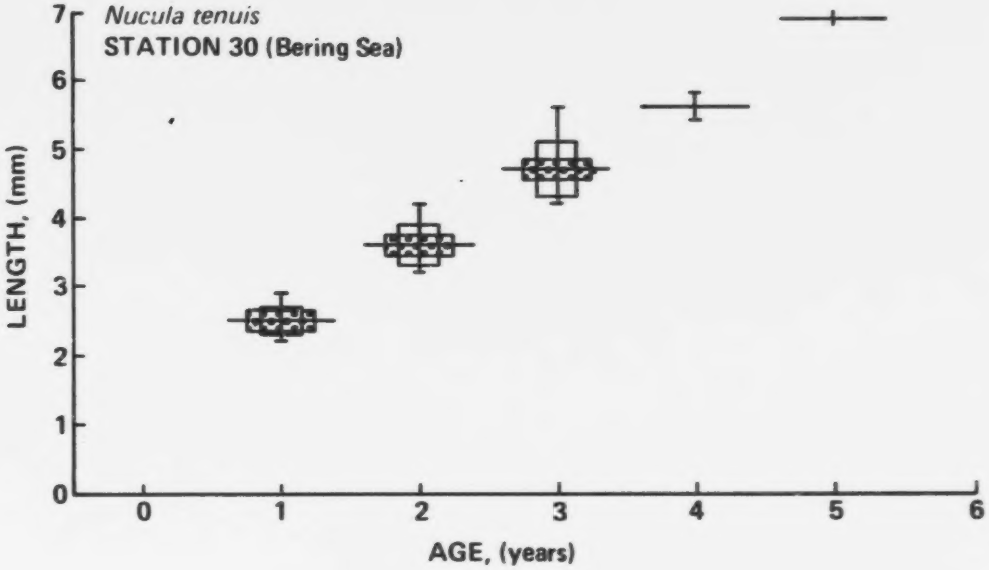


Figure 5.5. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 30 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

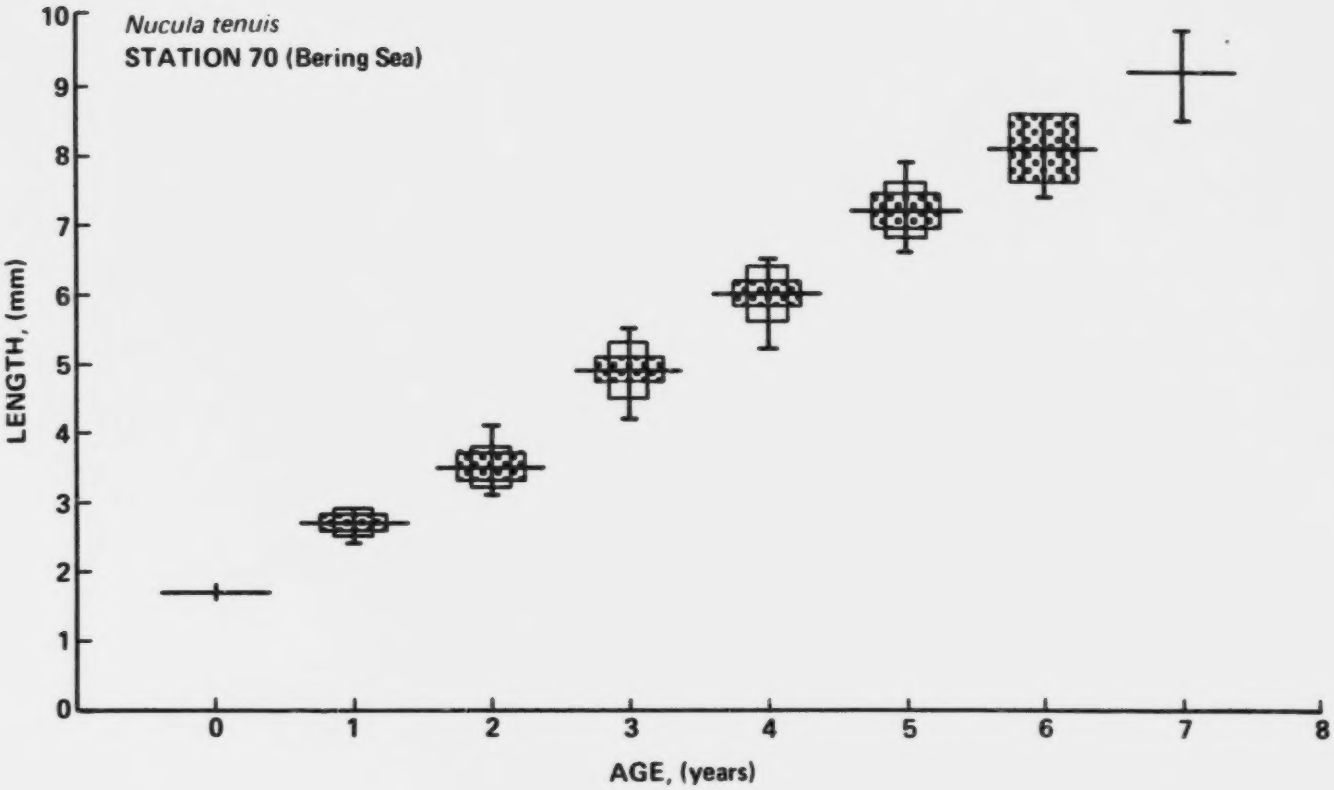


Figure 5.6. The relationship between shell length (mm) and age of *Nucula tenuis* from Station 70 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

TABLE 5.III

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM STATION 12 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	96	1.4	0.1	0.01	1.1 - 1.7
1	96	2.2	0.3	0.03	1.7 - 2.9
2	20	3.3	0.3	0.13	2.9 - 3.8
3	4	4.1	0.2	0.24	3.8 - 4.2
Total =	216				

TABLE 5.IV

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM STATION 18 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	4	3.7	0.2	0.25	3.5 - 4.0
3	8	4.9	0.5	0.40	4.0 - 5.8
4	17	6.1	0.5	0.27	5.0 - 6.9
5	6	7.1	0.6	0.51	6.5 - 7.8
6	13	8.4	0.6	0.36	7.4 - 9.3
7	6	9.8	0.8	0.72	8.7 - 10.6
Total =	54				

TABLE 5.V

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM STATION 19 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	1	2.0	0	0	2.0
2	10	3.7	0.3	0.21	3.3 - 4.2
3	23	4.8	0.5	0.22	4.0 - 5.7
4	6	5.8	0.2	0.22	5.4 - 6.1
5	10	7.2	0.7	0.47	6.3 - 8.9
6	12	8.8	0.7	0.44	7.4 - 9.8
7	23	10.1	0.6	0.25	9.0 - 11.4
8	10	10.5	0.5	0.36	10.0 - 11.3
9	5	12.3	0.7	0.68	11.6 - 13.3
Total	= 100				

TABLE 5.VI

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM STATION 30 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	7	2.5	0.2	0.18	2.2 - 2.9
2	18	3.6	0.3	0.17	3.2 - 4.2
3	27	4.7	0.4	0.15	4.2 - 5.6
4	2	5.6	0.3	0.58	5.4 - 5.8
5	1	6.9	0	0	6.9
Total =	55				

TABLE 5.VII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM STATION 38 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	5	1.7	0.1	0.14	1.5 - 1.8
1	6	2.4	0.2	0.22	2.1 - 2.7
2	13	3.4	0.3	0.21	2.7 - 4.0
3	2	4.7	0.0	0.00	4.7 - 4.7
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	1	10.2	0	0	10.2

Total = 27

TABLE 5.VIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULA TENUIS* FROM STATION 70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	1.7	0	0	1.7
1	11	2.7	0.2	0.12	2.4 - 2.9
2	14	3.5	0.3	0.20	3.1 - 4.1
3	20	4.9	0.4	0.18	4.2 - 5.5
4	20	6.0	0.4	0.19	5.2 - 6.5
5	10	7.2	0.4	0.25	6.6 - 7.9
6	5	8.1	0.5	0.48	7.4 - 8.6
7	2	9.2	0.9	1.90	8.5 - 9.8

Total = 83

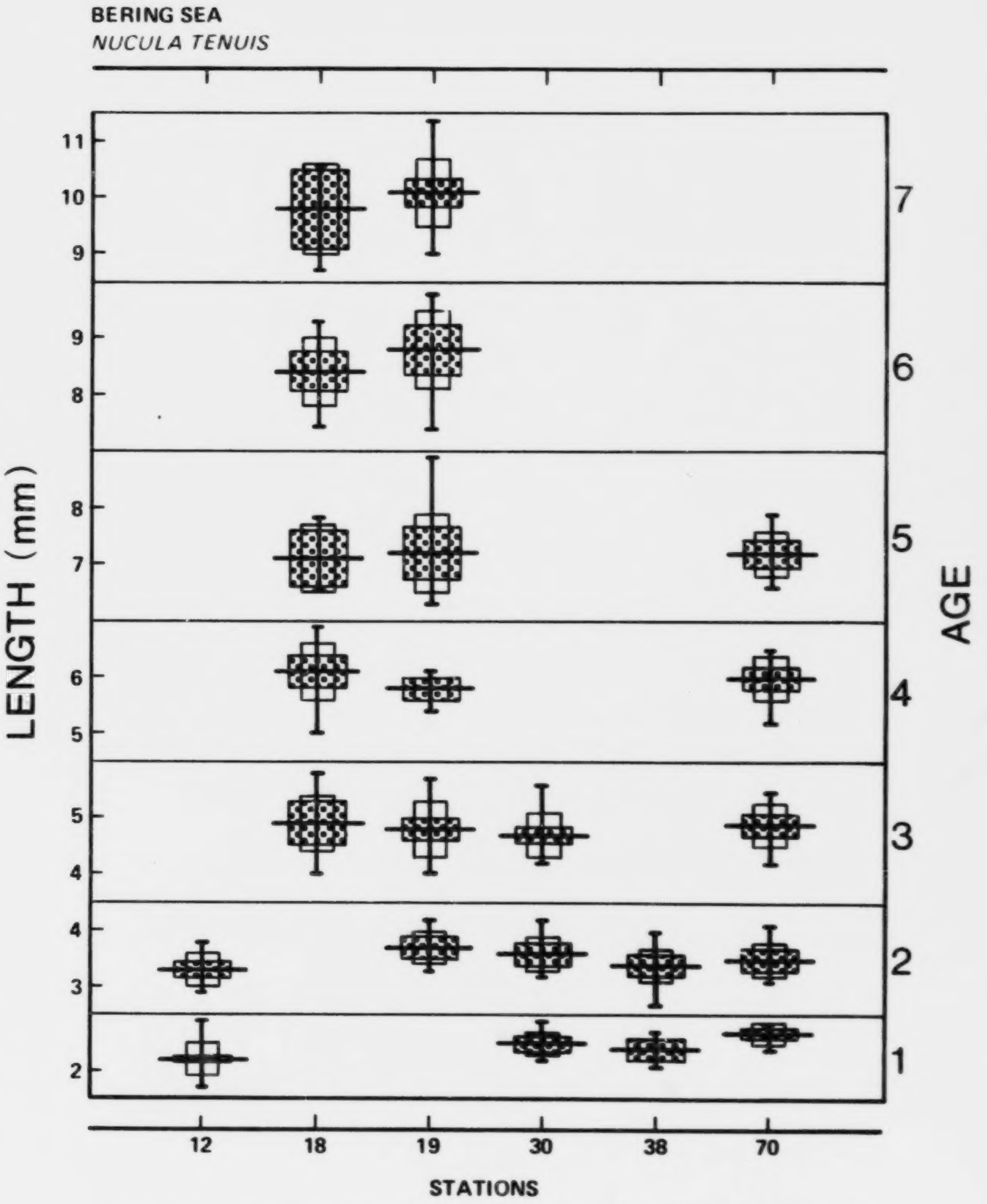


Figure 5.7. A comparison of shell length (mm) and age between six stations for *Nucula tenuis* in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

Station 12
(Bering Sea) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	Number in Age Class
1	2.2			96
2	2.3	3.3		20
3	2.3	3.2	4.1	4
	1973	1974	1975	Total
	**Y A F			120

*M S L = Mean Shell Length, mm
**Y A F = Year of Annulus Formation

Figure 5.8. The growth history of *Nucula tenuis* from Station 12 in the southeastern Bering Sea. Mean shell length in mm.

Station 18 (Bering Sea) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1								0
2	2.7	3.7						4
3	2.6	3.7	4.9					8
4	2.5	3.8	5.0	6.1				17
5	2.4	3.7	4.8	6.0	7.1			6
6	2.5	3.6	4.8	6.1	7.3	8.4		13
7	2.4	3.7	4.9	6.2	7.3	8.7	9.8	6
	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION							54

*M S L = Mean Shell Length

Figure 5.9. The growth history of *Nucula tenuis* from Station 18 in the southeastern Bering Sea. Mean shell length in mm.

Station 19 (Bering Sea) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	Number in Age Class
1	2.0									1
2	2.6	3.7								10
3	2.5	3.7	4.8							23
4	2.4	3.5	4.7	5.8						6
5	2.6	3.7	5.0	6.2	7.2					10
6	2.6	3.8	5.1	6.4	7.7	8.8				12
7	2.6	3.8	5.0	6.4	7.7	9.1	10.1			23
8	2.5	3.6	4.7	5.9	7.2	8.4	9.5	10.5		10
9	2.4	3.5	4.8	6.1	7.6	9.0	10.2	11.2	12.3	5
	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION									100

*M S L = Mean Shell Length

Figure 5.10. The growth history of *Nucula tenuis* from Station 19 in the southeastern Bering Sea. Mean shell length in mm.

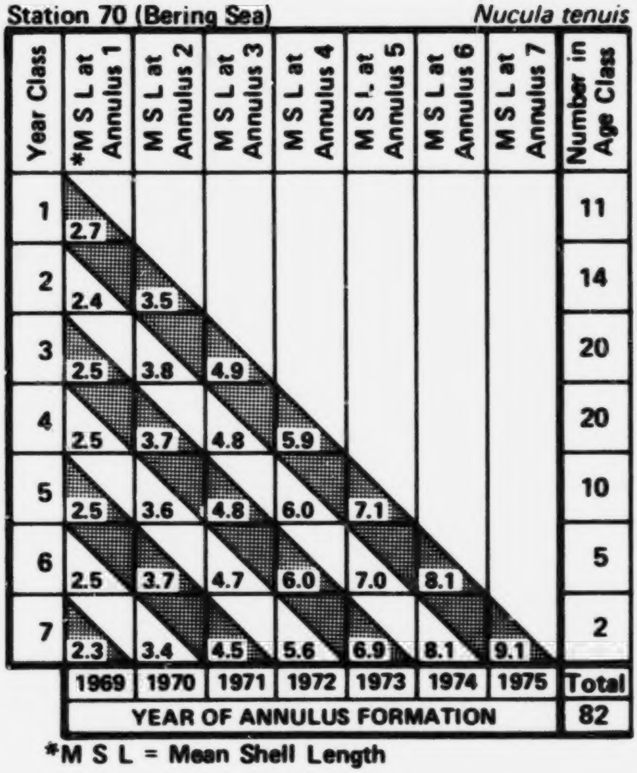
Station 30 (Bering Sea) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1	2.5					7
2	2.5	3.6				18
3	2.4	3.6	4.7			27
4	2.4	3.7	4.7	5.6		2
5	2.6	3.8	4.9	5.9	6.9	1
	1971	1972	1973	1974	1975	Total
	**Y A F					55

*M S L = Mean Shell Length, mm

** Y A F = Year of Annulus Formation

Figure 5.11. The growth history of *Nucula tenuis* from Station 30 in the southeastern Bering Sea. Mean shell length in mm.



Station 70 (Bering Sea) *Nucula tenuis*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	Number in Age Class
1	2.7							11
2	2.4	3.5						14
3	2.5	3.8	4.9					20
4	2.5	3.7	4.8	5.9				20
5	2.5	3.6	4.8	6.0	7.1			10
6	2.5	3.7	4.7	6.0	7.0	8.1		5
7	2.3	3.4	4.5	5.6	6.9	8.1	9.1	2
	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION							82

*M S L = Mean Shell Length

Figure 5.12. The growth history of *Nucula tenuis* from Station 70 in the southeastern Bering Sea. Mean shell length in mm.

The 0 year class *Nucula tenuis* appear to be fully retained by the screening process; therefore, mortality estimations include ages 0 through 9 (Table 5.IV; Fig. 5.13). The mortality calculations, column 4 of Table 5.IX, indicate mortality rates gradually increase with age. Individuals 1 year of age undergo 3.7% mortality; this rate increases to 54.7% by age 5. Only 3% of the specimens were older than 7 years; 100% mortality occurred by age 9.

A comparison of size at age (Tables 5.II-5.VIII; Figs. 5.2-5.7) and growth histories (Figs. 5.8-5.12) for *Nucula tenuis* from the Bering Sea stations examined indicate that growth rates are similar throughout the area (Tables 5.III-5.VIII), and have been relatively stable during the period of 1967 through 1974 (Figs. 5.8-5.12). The mean shell lengths for age classes 0 to 4 reported by Neiman (1964) for the southeastern Bering Sea are within 1 mm of those reported for this study; however, a difference of 2 mm and 5 mm exists in the mean shell length reported for age classes 5 and 6 (Table 5.X). The mean shell lengths of *N. tenuis*, age classes 0 to 7, from Cook Inlet (Feder, 1978) are all within 1 mm of those observed during the present study of the southeastern Bering Sea (Table 5.X). No other data on recruitment success and mortality rates are available for this species from the Bering Sea.

Nuculana fossa

A total of 321 *Nuculana fossa* from nine station (17, 18, 28, 30, 64, A69, 70, A70, and B86) were aged (Tables 5.I, 5.XI; Fig. 5.1). The graphical method of Hubbs and Hubbs (1953) illustrates the integrity of the age classes; none of the standard errors of the means overlap even when the sample sizes are small (Figs. 5.14-5.16). Annual recruitment success varied considerably at the nine stations (Tables 5.XII-5.XX). For example, 75% of *N. fossa* from Station 28 were in the 7 and 8 year classes, while 72% of the clams from Station 64 were 3 and 4 years of age. Variable recruitment at individual stations has been observed for *N. fossa* in Cook Inlet (Feder, 1978).

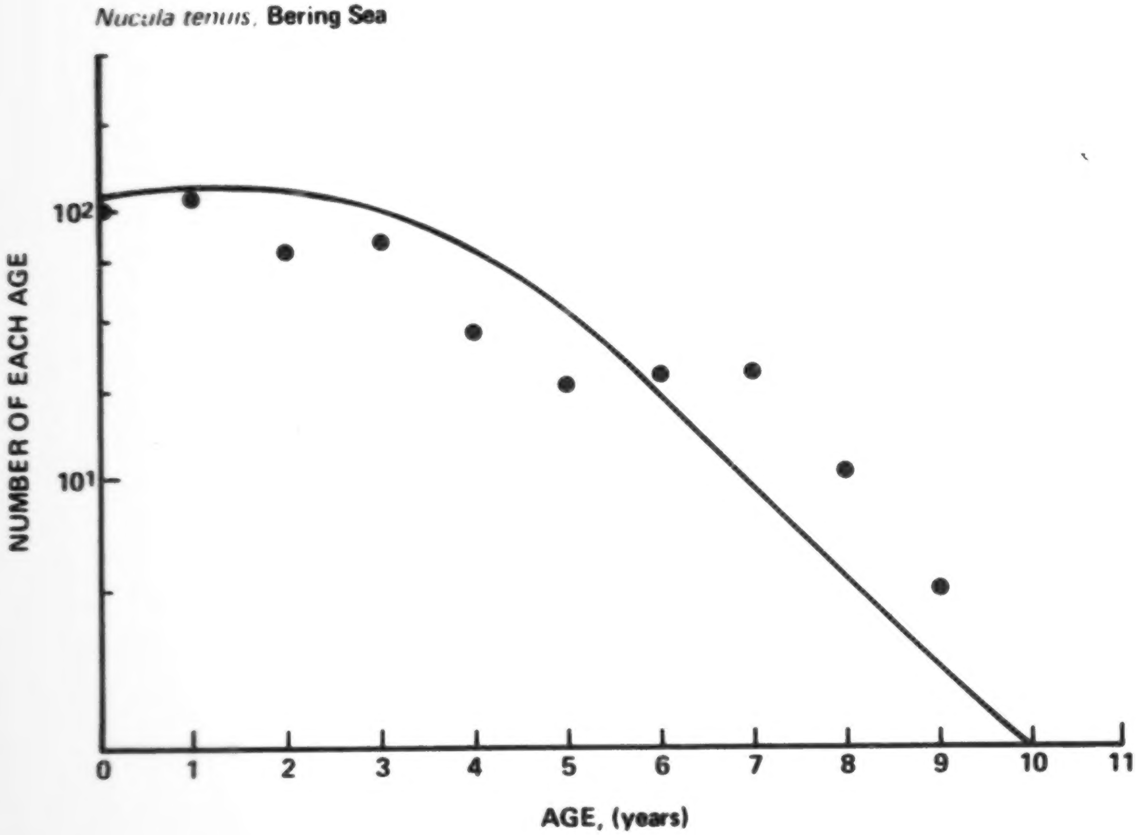
The annual increase in shell length for each of the size classes in the Bering Sea was typically 1.4 to 2.8 mm. The oldest and largest *Nuculana*

TABLE 5.IX

THE DISTRIBUTION OF *NUCULA TENUIS* AT EACH AGE AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY

Age	Number at Age from Original Data	Number at Age from Curve Figure 13*	Natural Mortality % from Curve Figure 13*
0	102	120	--
1	121	135	3.7
2	79	130	24.6
3	84	98	19.4
4	45	79	32.9
5	27	53	54.7
6	30	24	62.5
7	31	9	44.4
8	11	5	60.0
9	5	2	100.0
Total	= 535		

*Technique of Gruffydd (1974).



Nucula tenuis, Bering Sea

Figure 5.13. Graph of abundance *vs* age for all *Nucula tenuis* collected.

TABLE 5.X

A COMPARISON OF MEAN SHELL LENGTHS AND AGE FOR *NUCULA TENUIS* FROM THREE STUDIES

N = number of clams and MSL = mean shell length.

Age	Bering Sea* N	Bering Sea* MSL (mm)	Bering Sea** N	Bering Sea** MSL (mm)	Cook Inlet† N	Cook Inlet† MSL (mm)
0	102	1.4	10	1.0	30	1.7
1	121	2.2	27	1.5	55	2.3
2	79	3.5	110	3.9	44	3.3
3	84	4.8	57	5.3	34	4.3
4	45	6.0	39	6.9	30	5.3
5	27	7.2	25	9.3	7	6.2
6	30	8.5	8	13.7	0	--
7	31	10.0			2	9.3
8	11	10.5				
9	5	12.3				
Total	= 535	Total	= 276	Total	= 202	

* Present Report
**Neiman (1964)
† Feder (1978)

TABLE 5.XI

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM NINE STATIONS (17, 18, 28, 30, 64, A69, 70, A70, and B86) IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	2.5	0	0	2.5
1	37	4.0	0.6	0.10	2.8 - 5.2
2	37	6.0	0.6	0.11	5.0 - 7.1
3	75	8.6	1.1	0.12	6.4 - 10.6
4	76	10.9	0.7	0.08	9.6 - 12.3
5	30	12.8	0.7	0.25	11.5 - 14.3
6	16	14.2	0.5	0.26	13.1 - 15.3
7	32	17.0	0.7	0.12	15.6 - 18.3
8	11	18.4	0.5	0.32	17.7 - 19.3
9	6	19.9	0.5	0.49	19.1 - 20.6
Total	= 321				

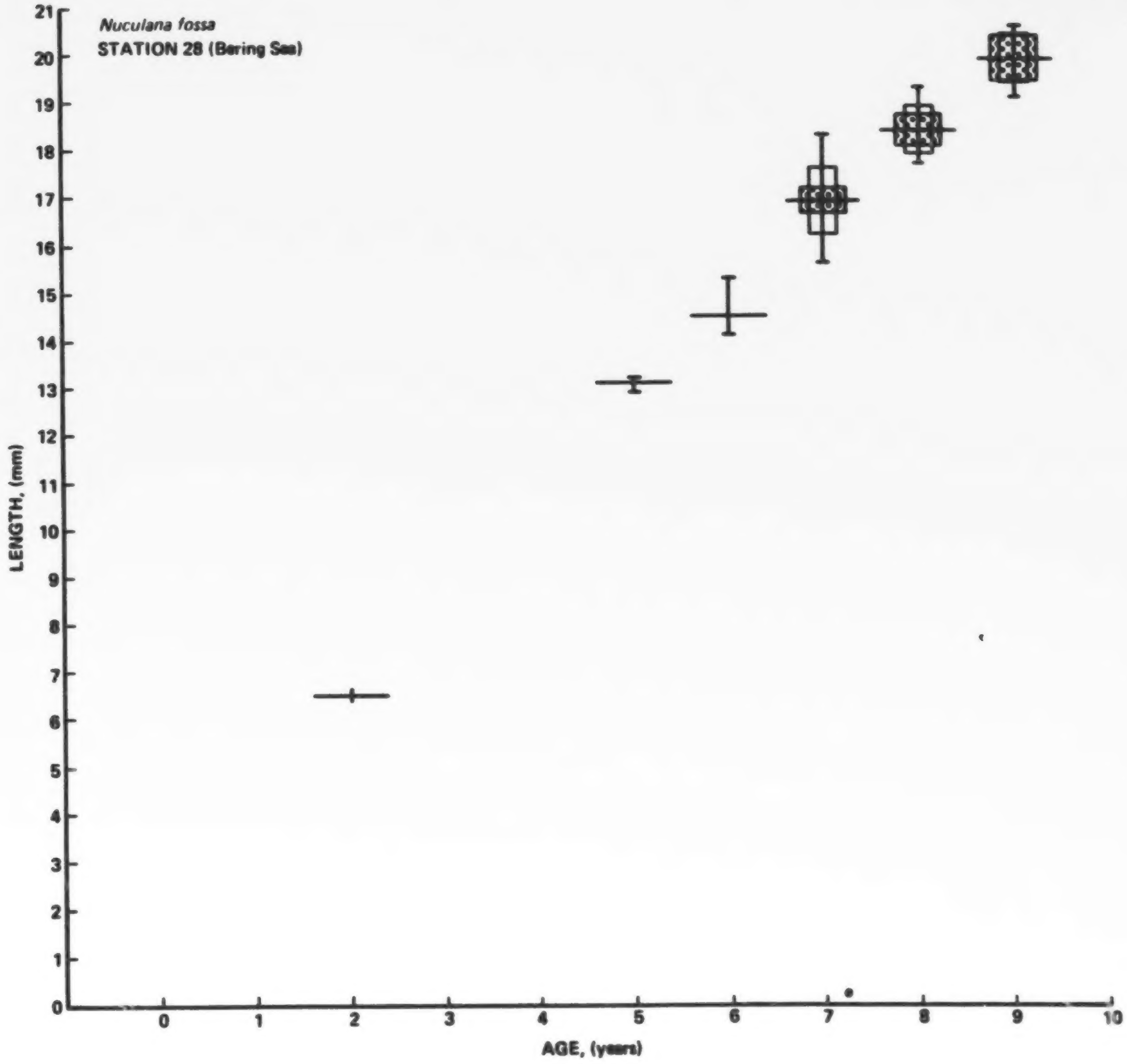


Figure 5.14. The relationship between shell length (mm) and age of *Nuculana fossa* from Station 28 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

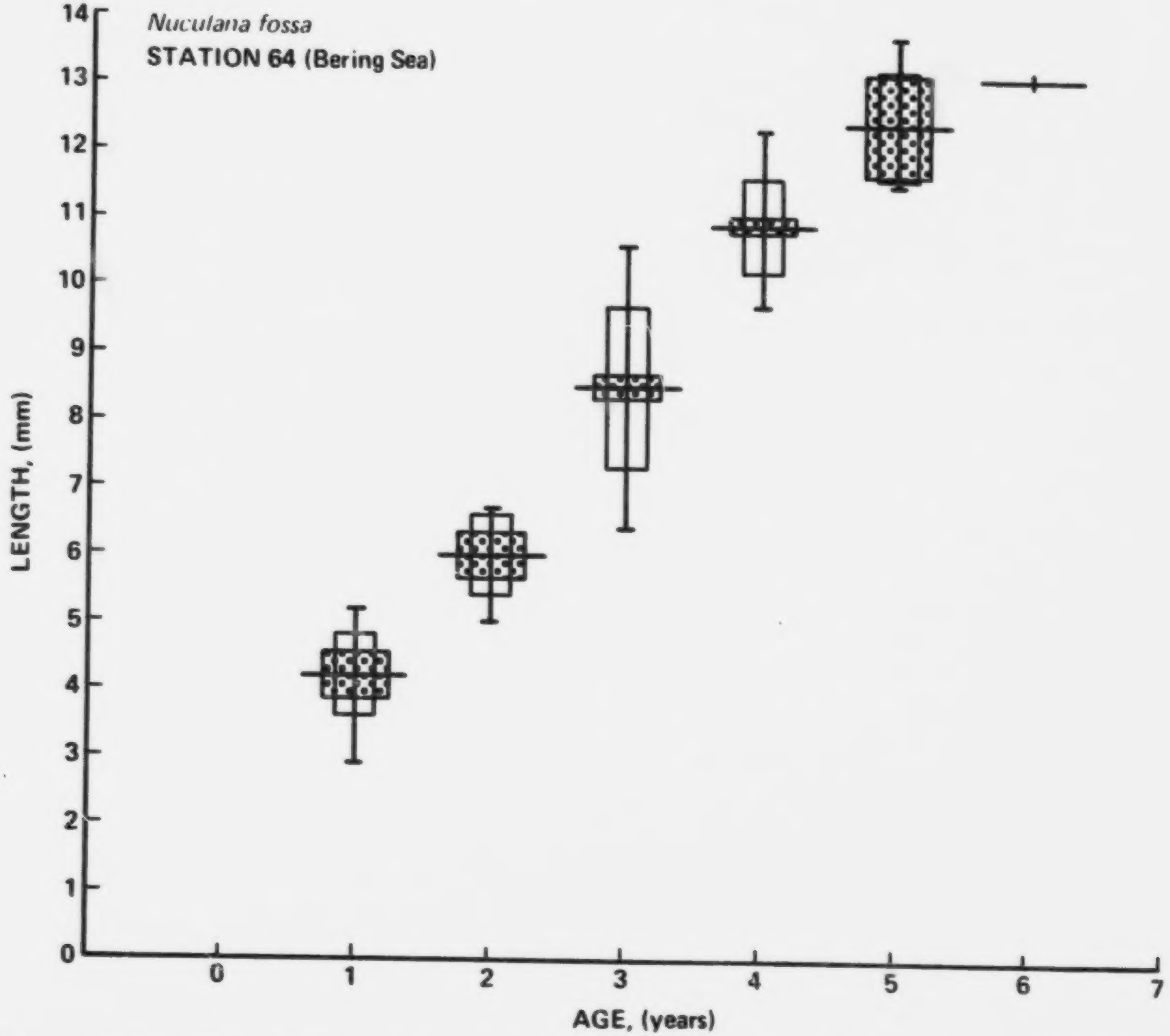


Figure 5.15. The relationship between shell length (mm) and age of *Nuculana fossa* from Station 64 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

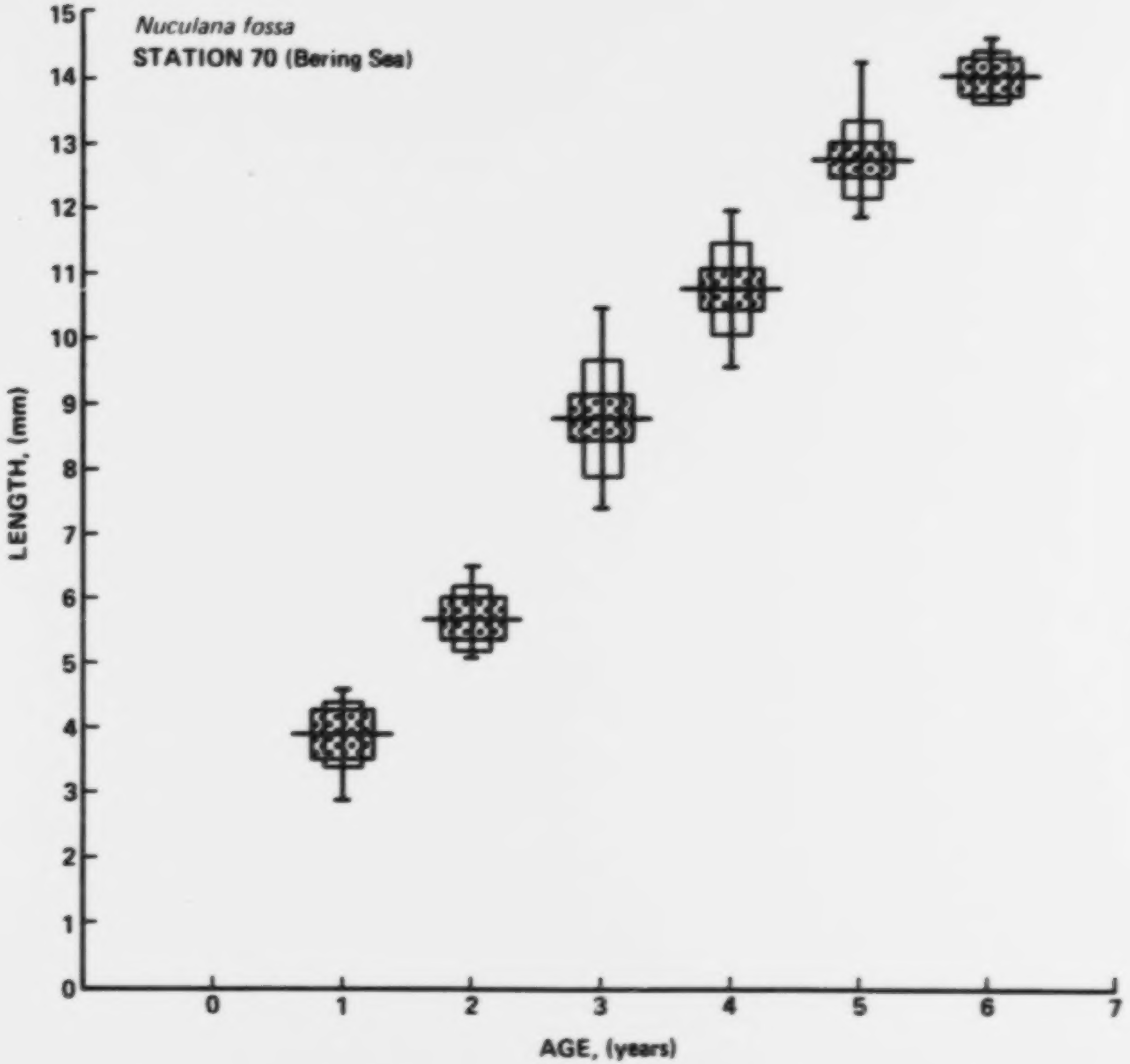


Figure 5.16. The relationship between shell length (mm) and age of *Nuculana fossa* from Station 70 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

BEST DOCUMENT AVAILABLE

TABLE 5.XII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION 17 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	3	4.2	0.4	0.59	3.8 - 4.6
Total	= 3				

TABLE 5.XIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION 18 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	3	4.3	0.1	0.15	4.2 - 4.4
2	0	--	--	--	--
3	2	8.3	1.1	2.19	7.5 - 9.0
4	0	--	--	--	--
5	1	13.7	0	0	13.7
6	0	--	--	--	--
7	2	17.3	0.3	0.58	17.1 - 17.5
Total	= 8				

TABLE 5.XIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION 28 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	1	6.5	0	0	6.5
3	0	--	--	--	--
4	0	--	--	--	--
5	2	13.1	0.2	0.44	12.9 - 13.2
6	5	14.5	0.5	0.51	14.1 - 15.3
7	30	16.9	0.7	0.27	15.6 - 18.3
8	11	18.4	0.5	0.32	17.7 - 19.3
9	6	19.9	0.5	0.49	19.1 - 20.6
Total	= 55				

TABLE 5.XV

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION 30 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	2.5	0	0	2.5
1	1	3.0	0	0	3.0
Total	= 2				

TABLE 5.XVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION 64 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	15	4.2	0.6	0.35	2.9 - 5.2
2	12	6.0	0.6	0.34	5.0 - 6.7
3	40	8.5	1.2	0.19	6.4 - 10.6
4	47	10.9	0.7	0.11	9.7 - 12.3
5	6	12.4	0.8	0.77	11.5 - 13.7
6	1	13.1	0	0	13.1
Total	= 121				

TABLE 5.XVII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION A69 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	1	2.8	0	0	2.8
2	5	6.5	0.7	0.74	5.3 - 7.1
3	3	8.5	0.3	0.47	8.1 - 8.7
4	1	10.7	0	0	10.7
Total	= 10				

TABLE 5.XVIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION 70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	9	3.9	0.5	0.39	2.9 - 4.6
2	10	5.7	0.5	0.32	5.1 - 6.5
3	26	8.8	0.9	0.36	7.4 - 10.5
4	20	10.8	0.7	0.31	9.6 - 12.0
5	19	12.8	0.6	0.28	11.9 - 14.3
6	8	14.1	0.4	0.30	13.7 - 14.7
Total	= 92				

TABLE 5.XIX

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION A70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	4	3.9	0.3	0.37	3.4 - 4.1
2	6	6.6	0.5	0.48	5.6 - 7.1
3	2	7.7	1.1	2.34	6.9 - 8.5
4	2	10.7	0.1	0.15	10.6 - 10.7
5	2	12.8	1.0	2.04	12.1 - 13.5
6	2	14.3	0.1	0.15	14.2 - 14.3
Total	= 18				

TABLE 5.XX

THE AGE COMPOSITION AND SHELL LENGTHS OF *NUCULANA FOSSA* FROM STATION B86 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	1	3.5	0	0	3.5
2	3	5.3	0.2	0.22	5.2 - 5.5
3	2	9.3	1.2	2.48	8.4 - 10.1
4	6	10.6	0.3	0.32	10.2 - 11.1
Total	= 12				

fossa collected was 9 years old and 20.6 mm in length. Growth rates of *N. fossa* from the nine stations were similar, although a few small significant differences, α = 0.05, did occur (Fig. 5.17).

From 1967 to 1975, the mean shell length at any given age for each station, as determined from the examinations of the growth histories of individual shells, showed some yearly variation (Figs. 5.18-5.20); however, 72 of the 79 mean annular lengths included in Figures 5.18-5.20 fall within the standard deviations calculated for each age class in the collection (Tables 5.XI-5.XX).

Year class three appears to be the first age group in which 100% of *Nuculana fossa* is retained by the screening process. Therefore, mortality estimations are restricted to age groups 3 through 9 (Table 5.XXI; Fig. 5.21). The mortality calculations, column 4 of Table 5.XXI, indicate mortality generally increases with age. Individuals 3 years of age undergo 10.3% mortality; this rate increases to 59.4% at 6 years of age. Only 5% of the specimens were older than 7 years. One hundred percent mortality had occurred by age 9.

A comparison of size at age (Tables 5.XI-5.XX; Figs. 5.14-5.17) and growth histories (Figs. 5.18-5.20) for *Nuculana fossa* from the Bering Sea stations examined indicates growth rates are similar throughout the area (Tables 5.XII-5.XX), and have been relatively stable for the period of 1967 through 1974 (Figs. 5.18-5.20). The mean shell lengths for age classes 0 to 4 in outer Bristol Bay (Neiman, 1964; called *Leda pernula* by Neiman, see Abbott, 1974) and 0 to 7 from Cook Inlet (Feder, 1978) are within 1.5 mm of those observed in the present study (Table 5.XXII). The mean shell length of 5-year-old individuals, as measured by Neiman (1964), is 3.2 mm larger than the mean length reported in the present study (Table 5.XXII). No other data on recruitment success and mortality rates are available for this species for the Bering Sea.

Yoldia amygdalea

A total of 129 *Yoldia amygdalea* from three stations (38, 70, and A70) were aged (Tables 5.I, 5.XXIII; Fig. 5.1). The graphical method of Hubbs

BEST DOCUMENT AVAILABLE

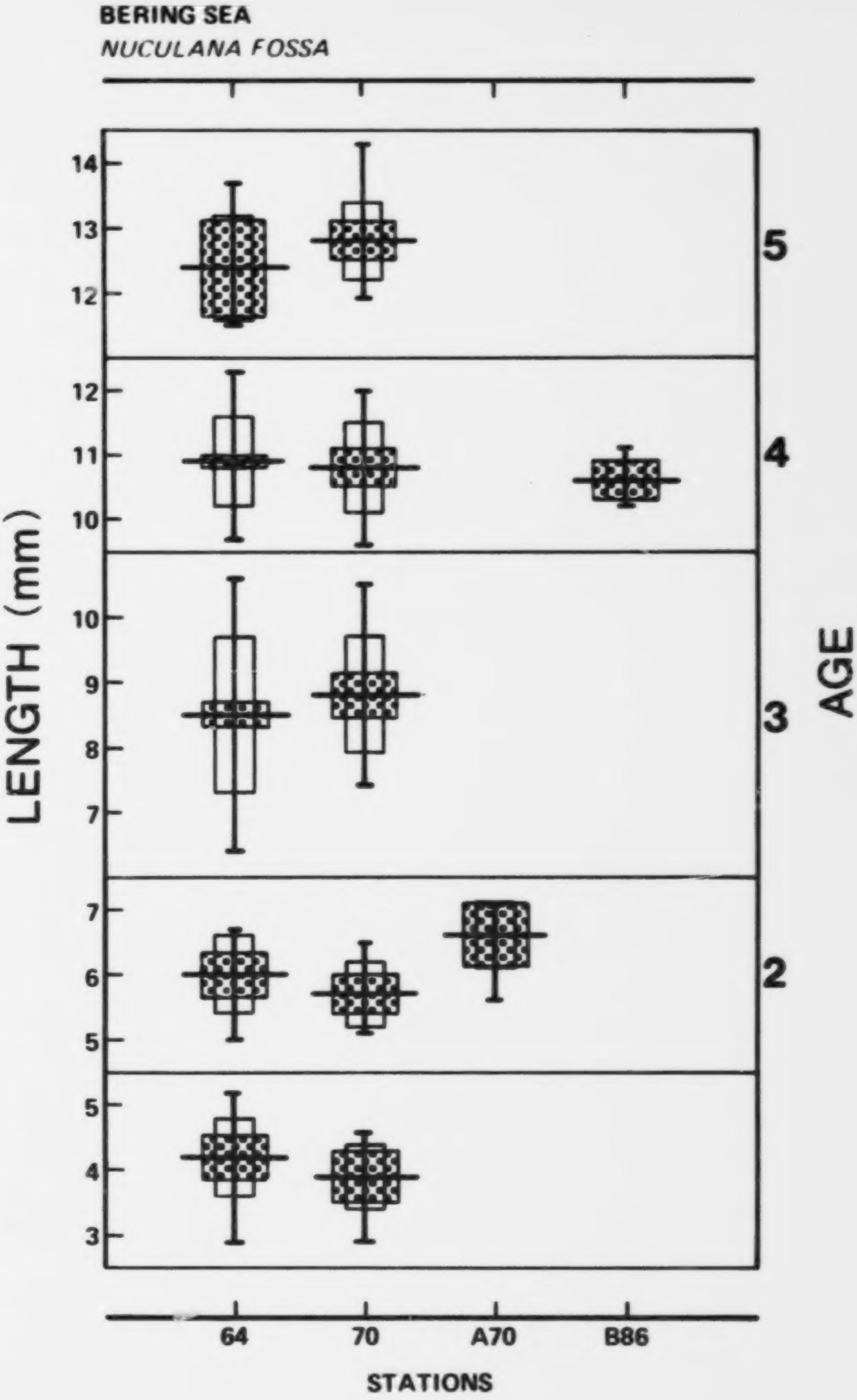


Figure 5.17. A comparison of shell length (mm) and age between four stations for *Nuculana fossa* in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

Station 28 (Bering Sea) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	Number in Age Class
1										0
2	3.5	6.5								1
3										0
4										0
5	3.5	6.3	9.4	11.5	13.1					2
6	3.6	5.7	8.8	11.1	13.1	14.5				5
7	4.0	5.8	8.4	11.2	13.4	15.2	16.9			30
8	3.9	5.9	8.4	11.1	13.3	15.3	16.8	18.4		11
9	3.8	5.7	8.6	11.2	13.3	15.0	16.4	18.4	19.9	6
	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION									55

*M S L = Mean Shell Length

Figure 5.18. The growth history of *Nuculana fossa* from Station 28 in the southeastern Bering Sea. Mean shell length in mm.

Station 64 (Bering Sea) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	Number in Age Class
1	4.2						15
2	4.2	6.0					12
3	4.1	6.6	8.5				40
4	4.1	6.4	9.0	10.9			47
5	3.7	6.0	8.2	10.4	12.4		6
6	3.9	6.1	8.2	9.6	11.5	13.1	1
	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION						121

*M S L = Mean Shell Length

Figure 5.19. The growth history of *Nuculana fossa* from Station 64 in the southeastern Bering Sea. Mean shell length in mm.

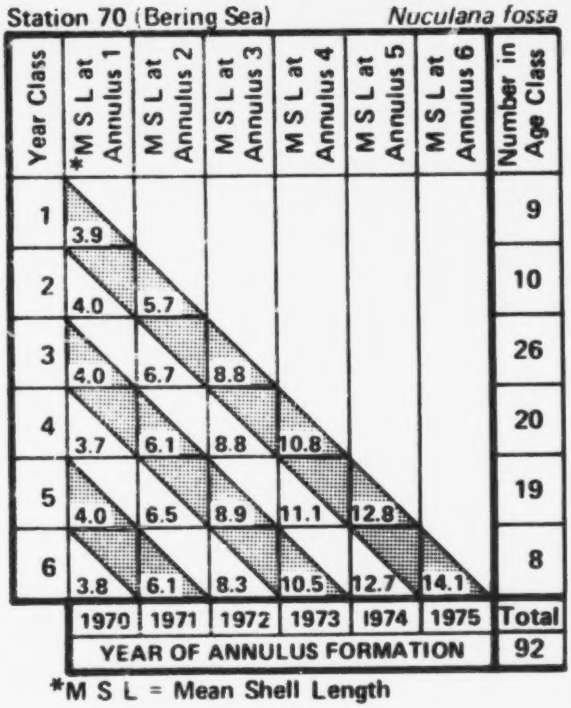
TABLE 5.XXI

THE DISTRIBUTION OF *NUCULANA FOSSA* AT EACH AGE AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY

Age	Number at Age from Original Data	Number at Age from Curve Figure 21*	Natural Mortality % from Curve Figure 21*
0	1	--	--
1	37	--	--
2	37	--	--
3	75	78	10.3
4	76	70	22.9
5	30	54	40.7
6	16	32	59.4
7	32	13	53.8
8	11	6	50.0
9	6	3	100.0
Total	= 321		

---

*Technique of Gruffydd (1974).



Station 70 (Bering Sea) *Nuculana fossa*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	Number in Age Class
1	3.9						9
2	4.0	5.7					10
3	4.0	6.7	8.8				26
4	3.7	6.1	8.8	10.8			20
5	4.0	6.5	8.9	11.1	12.8		19
6	3.8	6.1	8.3	10.5	12.7	14.1	8
	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION						92

*M S L = Mean Shell Length

Figure 5.20. The growth history of *Nuculana fossa* from Station 70 in the southeastern Bering Sea. Mean shell length in mm.

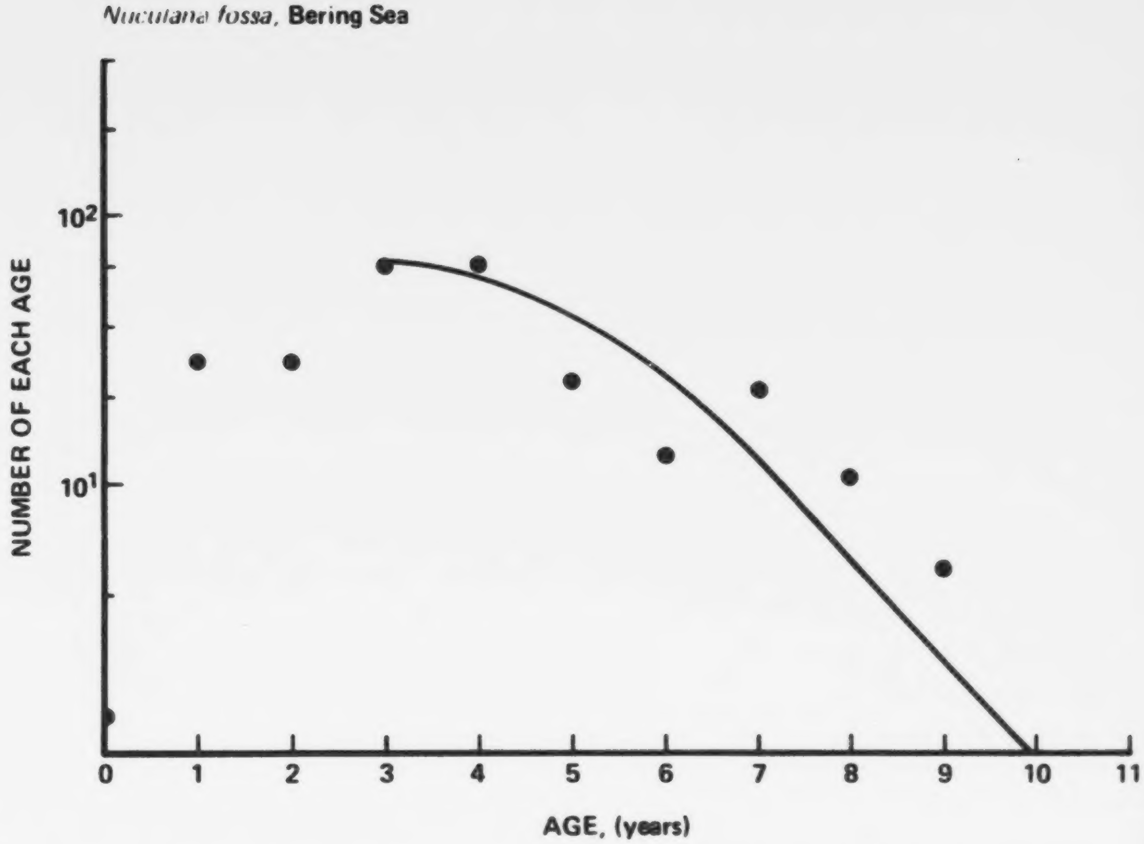


Figure 5.21. Graph of abundance *vs* age for all *Nuculana fossa* collected.

TABLE 5.XXII

A COMPARISON OF MEAN SHELL LENGTHS AND AGE FOR *NUCULANA FOSSA* FROM THREE STUDIES

N = number of clams and MSL = mean shell length.

Age	Bering Sea* N	Bering Sea* MSL (mm)	Bering Sea** N	Bering Sea** MSL (mm)	Cook Inlet† N	Cook Inlet† MSL (mm)
0	1	2.5	15	1.3	119	2.1
1	37	4.0	69	4.4	67	3.7
2	37	6.0	112	6.8	97	6.7
3	75	8.6	43	9.1	88	9.0
4	76	10.9	20	12.4	60	10.9
5	30	12.8	33	16.1	106	12.9
6	16	14.2			60	14.0
7	32	17.0			6	16.2
8	11	18.4				
9	6	19.9				
Total	= 321	Total	= 292	Total	= 603	

* Present Report
**Neiman (1964)
† Feder (1978)

TABLE 5.XXIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *YOLDIA AMYGDALEA* FROM THREE STATIONS (38, 70, and A70) IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	11	2.0	0.3	0.22	1.6 - 2.7
1	3	3.5	0.3	0.39	3.2 - 3.7
2	4	5.8	0.4	0.49	5.4 - 6.3
3	4	7.6	0.3	0.30	7.3 - 7.9
4	12	9.9	0.8	0.49	8.7 - 10.9
5	11	11.9	0.5	0.34	11.2 - 12.7
6	18	14.3	0.8	0.39	13.1 - 15.9
7	37	16.7	0.7	0.12	15.2 - 17.9
8	16	18.6	0.6	0.33	17.7 - 19.6
9	2	20.0	0.4	0.88	19.7 - 20.3
10	1	23.8	0	0	23.8
11	4	27.3	0.8	0.90	26.4 - 28.2
12	3	28.4	0.3	0.47	28.2 - 28.8
13	3	31.1	0.9	1.32	30.3 - 32.1
Total	= 129				

and Hubbs (1953) illustrates the integrity of the age classes; none of the standard errors of the mean overlap even when sample sizes are small (Fig. 5.22). Annual recruitment success varied considerably at the three stations (Tables 5.XXIV-5.XXVI). For example, 92% of *Y. amygdalea* from Station 28 were in the 0 year class, while 86% of the clams from Station A70 were between 4 and 8 years of age.

The annual increase in shell length for each of the size classes in the Bering Sea was typically 1.4 to 3.8 mm. Growths rates were similar for year classes 7 and 8 at Stations 70 and A70 (Fig. 5.23), and varied only slightly from year to year at Station A70 (Fig. 5.24). The oldest and largest *Y. amygdalea* collected was 13 years of age and 32.1 mm in length. Growth rates of *Y. amygdalea* from Stations 70 and A70 were compared at ages 7 and 8 (Fig. 5.24); Station A70 specimens grew at a slower rate.

From 1963 to 1975, the mean shell length at any given age, as determined from the examinations of the growth histories of individual shells, showed some yearly variation (Fig. 5.23). Although the sample size was small, 46 of the 87 mean annular lengths included in Figure 5.23 fall within the standard deviations calculated for each age class in the collection (Tables 5.XXIII-5.XXVI).

The sample size was too small for mortality calculations to be made. Only 10% of the specimens were older than 8 years.

A comparison of size at age (Tables 5.XXIII-5.XXVI; Fig. 5.22) and growth histories (Fig. 5.23) for *Yoldia amygdalea* from the Bering Sea stations examined indicates growth rates have been relatively stable during the period of 1963 through 1974 (Fig. 5.23). No other data on growth, recruitment or mortality rates of this clam are available for comparison.

Spisula polynyma

A total of 36 *Spisula polynyma* from two stations (9 and 55) were aged (Tables 5.I, 5.XXVII; Fig. 5.1). The graphical method of Hubbs and Hubbs (1953) illustrates the integrity of the age classes with the failure of any of the standard errors of the mean to overlap even when the sample sizes are small (Figs. 5.25-5.26). The majority, 89% of the 36 specimens collected

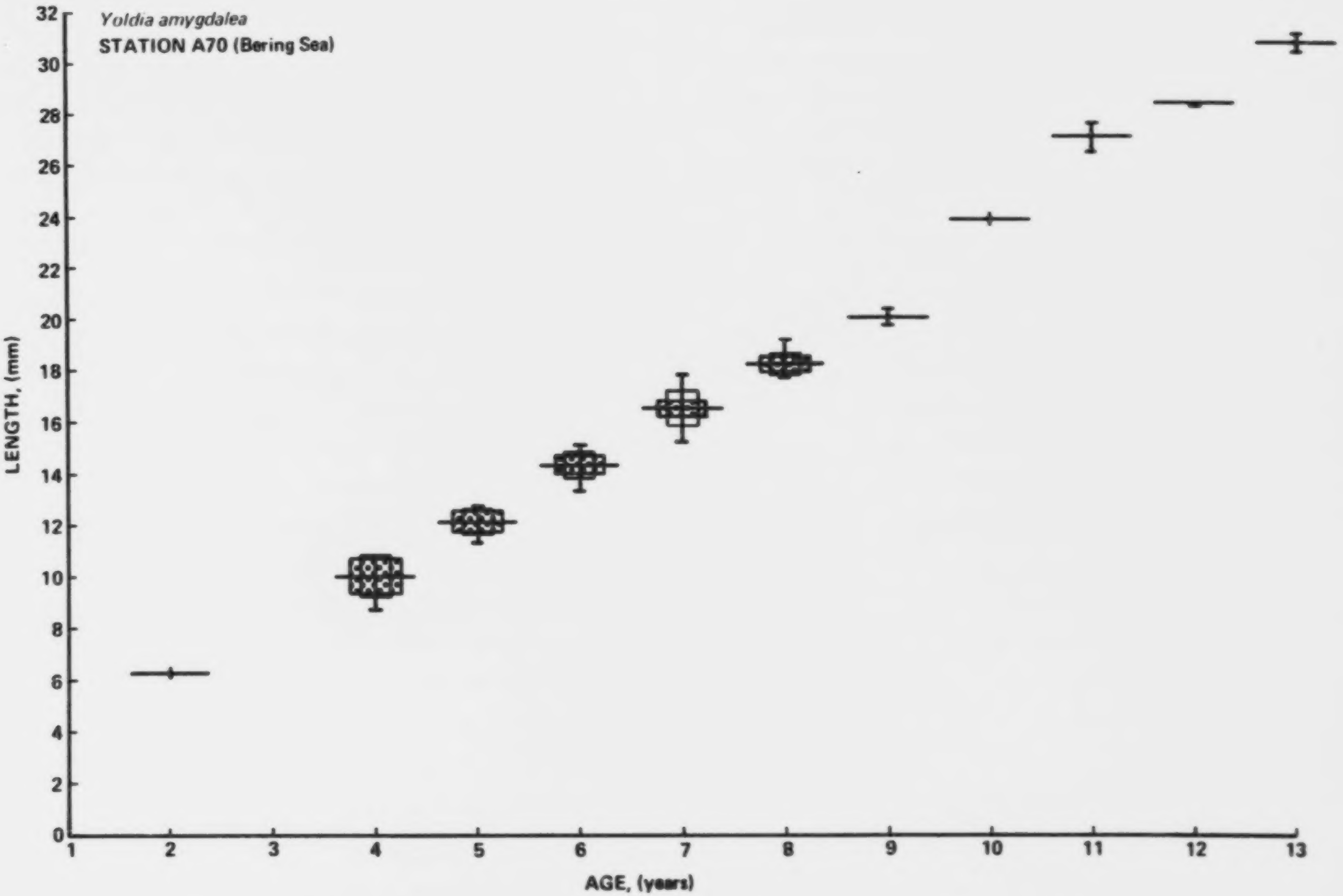


Figure 5.22. The relationship between shell length (mm) and age of *Yoldia amygdalea* at Station A70 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

BEST DOCUMENT AVAILABLE

TABLE 5.XXIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *YOLDIA AMYGDALEA* FROM STATION 38 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	11	2.0	0.3	0.22	1.6 - 2.7
1	1	3.2	0	0	3.2
Total	= 12				

TABLE 5.XXV

THE AGE COMPOSITION AND SHELL LENGTHS OF *YOLDIA AMYGDALEA* FROM STATION 70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	2	3.7	0.1	0.15	3.6 - 3.7
2	3	5.6	0.3	0.39	5.4 - 5.9
3	4	7.6	0.3	0.30	7.3 - 7.9
4	5	9.7	0.8	0.80	9.0 - 10.9
5	4	11.6	0.3	0.34	11.2 - 11.9
6	5	14.4	1.3	1.34	13.1 - 15.9
7	12	17.1	0.6	0.35	16.4 - 17.9
8	6	19.2	0.2	0.21	19.0 - 19.6
9	0	--	--	--	--
10	0	--	--	--	--
11	2	27.7	0.8	1.61	27.1 - 28.2
12	1	28.8	0	0	28.8
13	1	32.1	0	0	32.1
Total	= 45				

TABLE 5.XXVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *YOLDIA AMYGDALEA* FROM STATION A70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	1	6.3	0	0	6.3
3	0	--	--	--	--
4	7	10.0	0.8	0.70	8.7 - 10.8
5	7	12.1	0.5	0.42	11.3 - 12.7
6	13	14.3	0.5	0.31	13.3 - 15.1
7	25	16.5	0.7	0.30	15.2 - 17.8
8	10	18.2	0.4	0.31	17.7 - 19.1
9	2	20.0	0.4	0.88	19.7 - 20.3
10	1	23.8	0	0	23.8
11	2	27.0	0.8	1.61	26.4 - 27.5
12	2	28.3	0.1	0.15	28.2 - 28.3
13	2	30.7	0.5	1.02	30.3 - 31.0
Total	= 72				

Station A70 (Bering Sea) *Yoldia amygdale*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	Number in Age Class
1														0
2	3.4	6.3												1
3														0
4	3.5	6.0	8.0	10.0										7
5	3.6	5.8	8.0	10.1	12.1									7
6	3.9	6.2	8.2	10.4	12.4	14.3								13
7	3.8	6.0	8.3	10.8	13.0	14.9	16.5							25
8	3.8	6.1	8.5	11.2	13.1	14.8	16.6	18.2						10
9	3.3	5.3	8.4	10.6	12.9	15.3	17.0	18.5	20.0					2
10	3.2	5.9	7.9	10.3	12.7	14.5	17.6	19.2	22.4	23.8				1
11	4.2	6.4	8.6	10.8	13.4	15.2	17.4	20.0	21.5	24.4	27.0			2
12	3.7	5.7	7.7	10.7	12.7	15.2	18.1	20.2	22.0	24.6	26.5	28.3		2
13	4.1	5.4	7.9	10.9	13.4	16.0	18.3	19.6	21.5	23.7	26.1	28.7	30.7	2
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION													72

*M S L = Mean Shell Length

Figure 5.23. The growth history of *Yoldia amygdalea* from Station A70 in the southeastern Bering Sea. Mean shell length in mm.

BEST DOCUMENT AVAILABLE

TABLE 5.XXVII

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM TWO STATIONS (9 and 55) IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	8	3.9	0.6	0.44	3.3 - 5.0
1	24	6.9	1.0	0.44	4.8 - 9.0
2	3	10.2	0.3	0.44	9.9 - 10.5
3	1	16.4	0	0	16.4
Total	= 36				

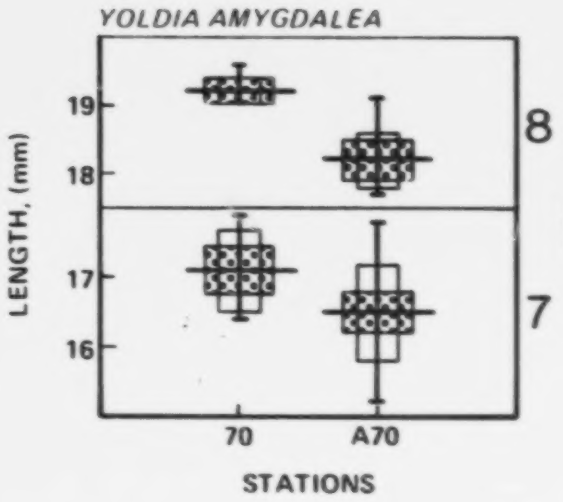


Figure 5.24. A comparison of shell length (mm) and age between two stations for *Yoldia amygdalea* in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

BEST DOCUMENT AVAILABLE

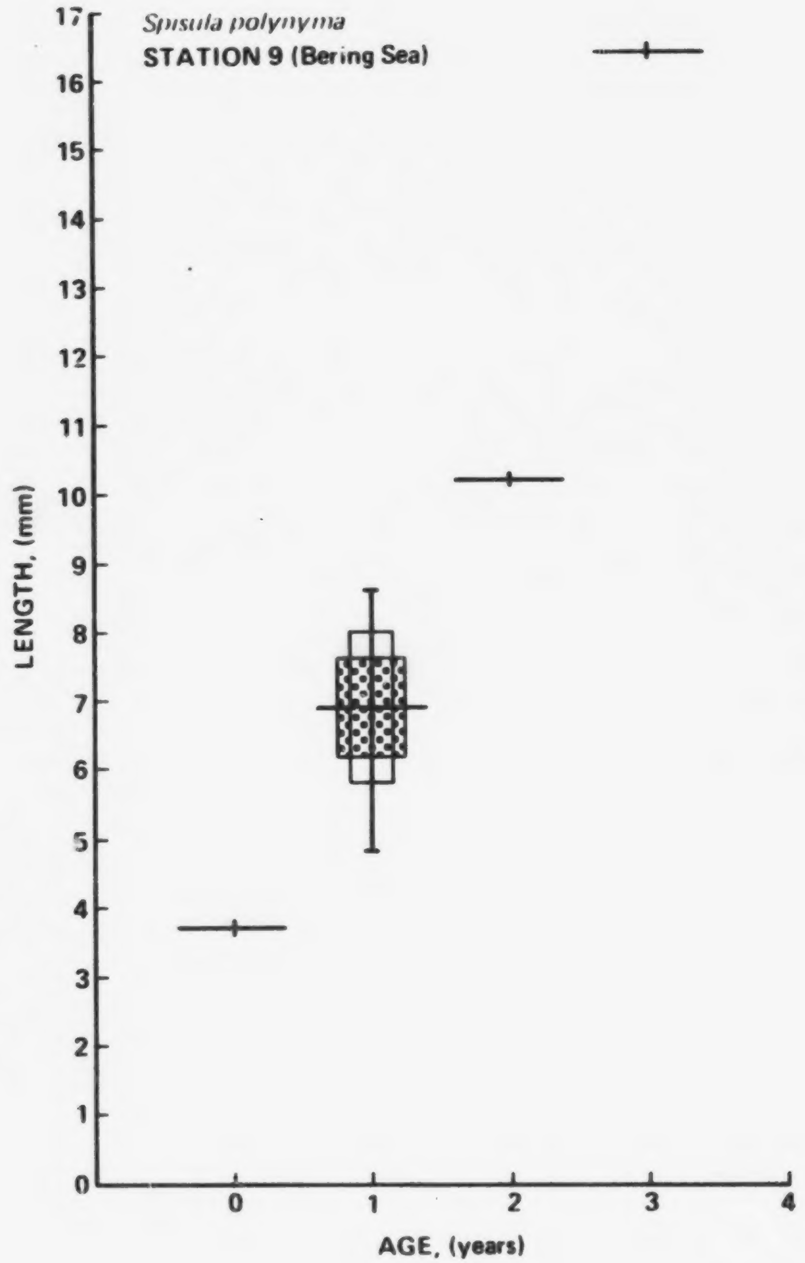


Figure 5.25. The relationship between shell length (mm) and age of *Spisula polynyma* at Station 9 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box and range by the vertical line.

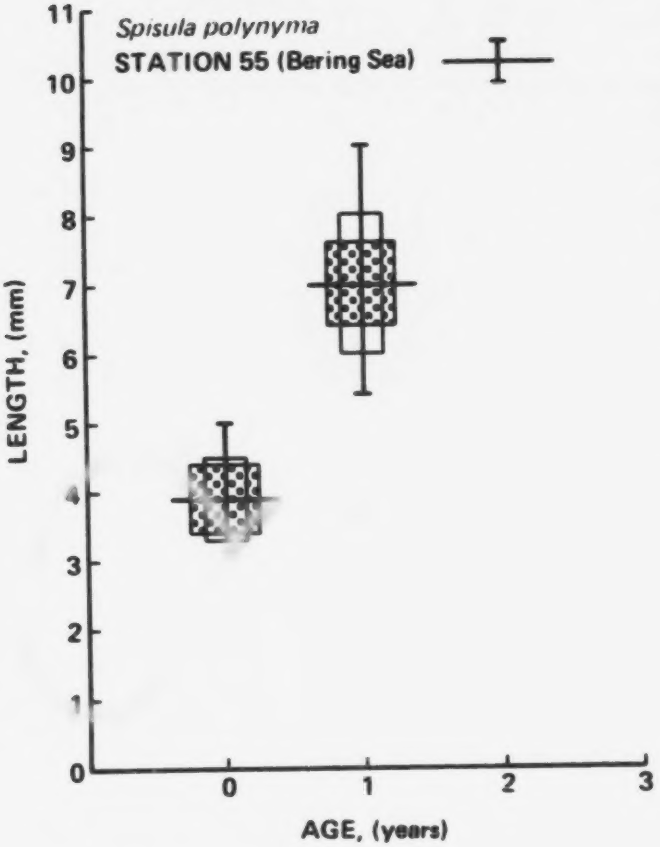


Figure 3.26. The relationship between shell length (mm) and age of *Spisula polynyma* at Station 55 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

were between 0 and 1 years of age. Annual recruitment and growth for the age classes captured were similar at both stations (Tables 5.XXVII-5.XXIX; Fig. 5.27). The oldest and largest *S. polynyma* collected was 3 years of age and 16.4 mm in length. Larger and older *S. polynyma* are not captured with a pipe dredge. The sample size is too small and biased toward young clams to calculate growth histories and mortalities.

Data for *Spisula polynyma* collected by a hydraulic clam dredge in the eastern Bering Sea can be found in Appendix A of Feder *et al.*, 1978b. Information on growth, recruitment, and mortality rates for mature Bering Sea *S. polynyma* are also available in Section 4, Appendix 4.B.

Tellina lutea

A total of 71 *Tellina lutea* from six stations (4, 5, 6, 22, 23, and 25) were aged (Tables 5.I, 5.XXX; Fig. 5.1). The graphical method of Hubbs and Hubbs (1953) illustrates the integrity of the age classes with the failure of all but one of the standard errors of the mean overlap even when the sample sizes are small (Fig. 5.28). Annual recruitment success varied considerably at the six stations (Tables 5.XXXI-5.XXXVI). For example, 100% of *T. lutea* from Station 4 were 15 years of age, while 47% of the clams from Station 23 were between the ages of 5 and 6.

The annual increase in shell length for each of the size classes in the Bering Sea was typically 0.9 to 9.1 mm. Growth rates varied only slightly from year to year (Fig. 5.29). The oldest *T. lutea* collected was 15 years of age, and the largest clam taken was 83.0 mm in length.

From 1963 through 1973, the mean shell length at any given age, as determined from the examinations of the growth histories of individual shells, showed some yearly variation (Fig. 5.29). Although the sample was small, 56 of the 73 mean annular length included in Figure 5.29 fall within the standard deviations calculated for each age class in the collection (Tables 5.XXX-5.XXXVI).

The sample size is too small to calculate mortalities. Only 8% of the specimens were older than 13 years.

TABLE 5.XXVIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM STATION 9 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	3.7	0	0	3.7
1	10	6.9	1.1	0.72	4.8 - 8.6
2	1	10.2	0	0	10.2
3	1	16.4	0	0	16.4
Total	= 13				

TABLE 5.XXIX

THE AGE COMPOSITION AND SHELL LENGTHS OF *SPISULA POLYNYMA* FROM STATION 55 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	7	3.9	0.6	0.50	3.3 - 5.0
1	14	7.0	1.0	0.60	5.4 - 9.0
2	2	10.2	0.4	0.88	9.9 - 10.5
Total	= 23				

TABLE 5.XXX

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM SIX STATIONS (4, 5, 6, 22, 23, and 25) IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	1	8.7	0	0	8.7
3	3	12.8	1.8	2.56	11.0 - 14.5
4	5	21.9	2.7	2.76	18.2 - 25.4
5	3	30.0	2.7	3.95	27.2 - 32.6
6	9	31.4	4.4	3.21	23.3 - 36.9
7	4	39.5	3.6	4.24	35.2 - 42.9
8	3	42.0	2.6	3.78	40.0 - 44.9
9	4	53.4	10.8	12.85	41.0 - 64.3
10	7	57.2	5.0	4.24	50.7 - 63.0
11	14	63.8	5.4	3.08	54.0 - 75.0
12	3	64.7	9.9	14.49	54.4 - 74.2
13	9	62.8	9.0	6.59	45.4 - 75.6
14	3	72.9	9.7	14.19	63.6 - 83.0
15	3	72.3	6.2	8.98	66.9 - 79.0
Total	= 71				

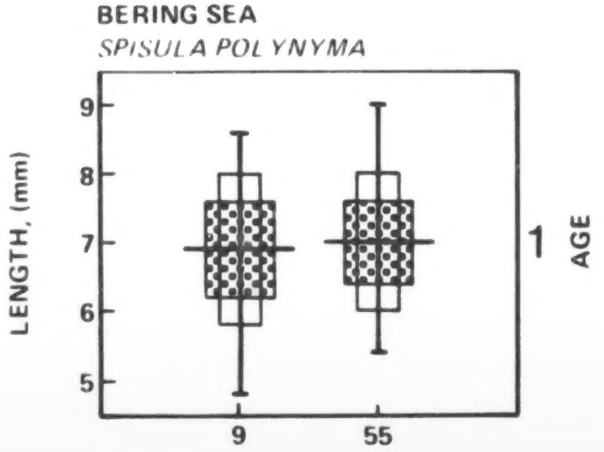


Figure 5.27. A comparison of shell length (mm) and age between two stations for *Spisula polynyma* in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

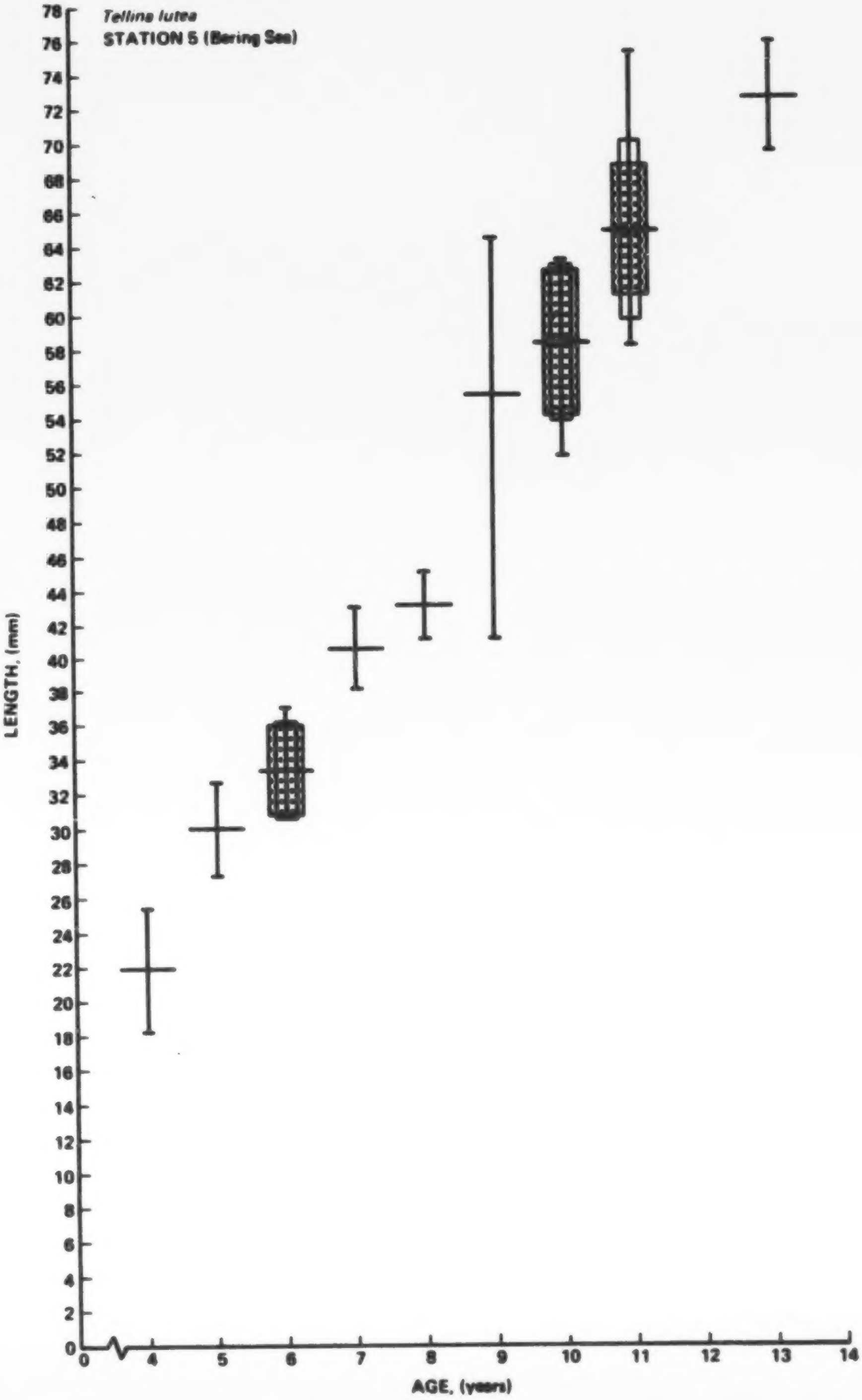


Figure 5.28. The relationship between shell length (mm) and age of *Tellina lutea* at Station 5 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

TABLE 5.XXXI

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM STATION 4 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	0	--	--	--	--
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	0	--	--	--	--
12	0	--	--	--	--
13	0	--	--	--	--
14	0	--	--	--	--
15	3	72.3	6.2	8.98	66.9 - 79.0
Total	= 3				

TABLE 5.XXXII

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM STATION 5 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	0	--	--	--	--
4	4	21.9	3.1	3.68	18.2 - 25.4
5	3	30.0	2.7	3.95	27.2 - 32.6
6	6	33.3	2.8	2.59	30.5 - 36.9
7	2	40.5	3.5	7.15	38.0 - 42.9
8	2	43.0	2.8	5.69	41.0 - 44.9
9	3	55.2	12.4	18.15	41.0 - 64.3
10	6	58.2	4.5	4.20	51.6 - 63.0
11	9	64.7	5.2	3.76	58.0 - 75.0
12	0	--	--	--	--
13	2	72.4	4.5	9.34	69.2 - 75.6
Total	= 37				

TABLE 5.XXXIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM STATION 6 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	0	--	--	--	--
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	1	41.9	0	0	41.9
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	1	64.4	0	0	64.4
12	1	74.2	0	0	74.2
13	1	73.0	0	0	73.0
14	1	72.2	0	0	72.2
Total	= 5				

TABLE 5.XXXIV

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM STATION 22 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	1	8.7	0	0	8.7
3	0	--	--	--	--
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	0	--	--	--	--
12	0	--	--	--	--
13	5	60.4	1.8	1.81	58.7 - 62.3
14	2	73.3	13.7	28.31	63.6 - 83.0
Total	= 8				

TABLE 5.XXXV

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM STATION 23 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	3	12.8	1.8	2.56	11.0 - 14.5
4	1	21.9	0	0	21.9
5	0	--	--	--	--
6	3	27.5	4.9	7.15	23.3 - 32.9
7	1	35.2	0	0	35.2
8	1	40.0	0	0	40.0
9	1	47.9	0	0	47.9
10	1	50.7	0	0	50.7
11	2	56.0	2.8	5.84	54.0 - 58.0
12	1	54.4	0	0	54.4
13	1	45.4	0	0	45.4
Total	= 15				

TABLE 5.XXXVI

THE AGE COMPOSITION AND SHELL LENGTHS OF *TELLINA LUTEA* FROM STATION 25 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	0	--	--	--	--
3	0	--	--	--	--
4	0	--	--	--	--
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	2	67.1	2.6	5.40	65.2 - 68.9
12	1	65.6	0	0	65.6
Total	= 3				

Station 5 (Bering Sea) *Tellina lutea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	M S L at Annulus 12	M S L at Annulus 13	Number in Age Class
1														0
2														0
3														0
4	6.2	11.4	16.8	21.9										4
5	6.1	11.9	19.3	25.9	30.0									3
6	5.7	10.6	15.6	22.5	29.3	33.3								6
7	6.8	11.9	17.7	24.2	30.5	36.7	40.5							2
8	5.9	9.8	15.9	22.8	29.8	35.8	40.0	43.0						2
9	6.5	11.3	17.1	23.9	30.2	36.2	43.1	50.6	55.2					3
10	5.6	9.4	15.1	21.2	28.3	36.2	42.8	48.6	54.4	58.2				6
11	5.5	9.6	15.0	21.5	28.5	35.3	41.8	47.9	53.8	60.2	64.7			9
12														0
13	6.3	11.9	18.1	26.5	34.0	39.6	43.8	52.1	57.3	61.2	65.8	69.2	72.4	2
	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION													37

*M S L = Mean Shell Length

Figure 5.29. The growth history of *Tellina lutea* from Station 5 in the southeastern Bering Sea. Mean shell length in mm.

A comparison of size at age (Tables 5.XXX-5.XXXVI) and growth histories (Fig. 5.29) for *Tellina lutea* from the Bering Sea stations examined indicates growth rates have been relatively stable during the period of 1963 through 1974 (Fig. 5.29). No other data on growth, recuitment or mortality rates of this clam are available for comparison.

Macoma calcarea

A total of 936 *Macoma calcarea* from four stations (28, 64, 70, and A70) were aged (Tables 5.I, 5.XXXVII; Fig. 5.1). The graphical method of Hubbs and Hubbs (1953) illustrates the integrity of the age classes with the failure to any of the standard errors of the mean overlap even when sample sizes are small (Figs. 5.30-5.33). Annual recruitment success varied considerably at the four stations (Tables 5.XXXVIII-5.XLI). For example, 72% of *M. calcarea* from Station 64 were in year class two, while 86% of the clams from Station 28 were between 4 and 5 years of age. Variable recruitment at individual stations has also been observed for *M. calcarea* in Cook Inlet (Feder, 1978).

The annual increase in shell length for each of the size classes in the Bering Sea was typically 1.5 to 3.7 mm. The oldest and largest *Macoma calcarea* collected was 11 years of age and 48.8 mm in length. Growth rates of *M. calcarea* from Stations 28, 64, and A70 were similar (Fig. 5.34). Individuals from ages 1 through 4 from Station 70 were slightly smaller than those of the same ages from the other three stations. This difference in growth rate at the latter station, while slight, was significant ($\alpha = 0.05$; Fig. 5.38). No significant difference was observed for 5 year olds from Stations 28 and 70.

From 1965 to 1975, the mean shell length at any given age, as determined from the examinations of the growth histories of individual shells, showed some yearly variations; however, 66 of the 94 mean annular lengths reported in Figures 5.35-5.38 fall within the standard deviations calculated for each age class in the collection (Tables 5.XXXVII-5.XLI).

Year class two of *Macoma calcarea* is the first age group in which 100% of the individuals appear to be retained by the screening process. Therefore,

BEST DOCUMENT AVAILABLE

TABLE 5.XXXVII

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM FOUR STATIONS (28, 64, 70, and A70) IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	2.1	0	0	2.1
1	45	4.3	0.6	0.09	3.0 - 5.2
2	286	6.4	0.8	0.15	4.3 - 8.8
3	281	8.2	1.1	0.06	5.8 - 11.8
4	200	10.2	1.4	0.10	7.7 - 15.2
5	110	12.9	1.4	0.13	10.2 - 15.8
6	10	15.6	1.9	1.32	13.2 - 18.5
7	0	--	--	--	--
8	1	20.7	0	0	20.7
9	1	25.1	0	0	25.1
10	0	--	--	--	--
11	1	48.8	0	0	48.8
Total	= 936				

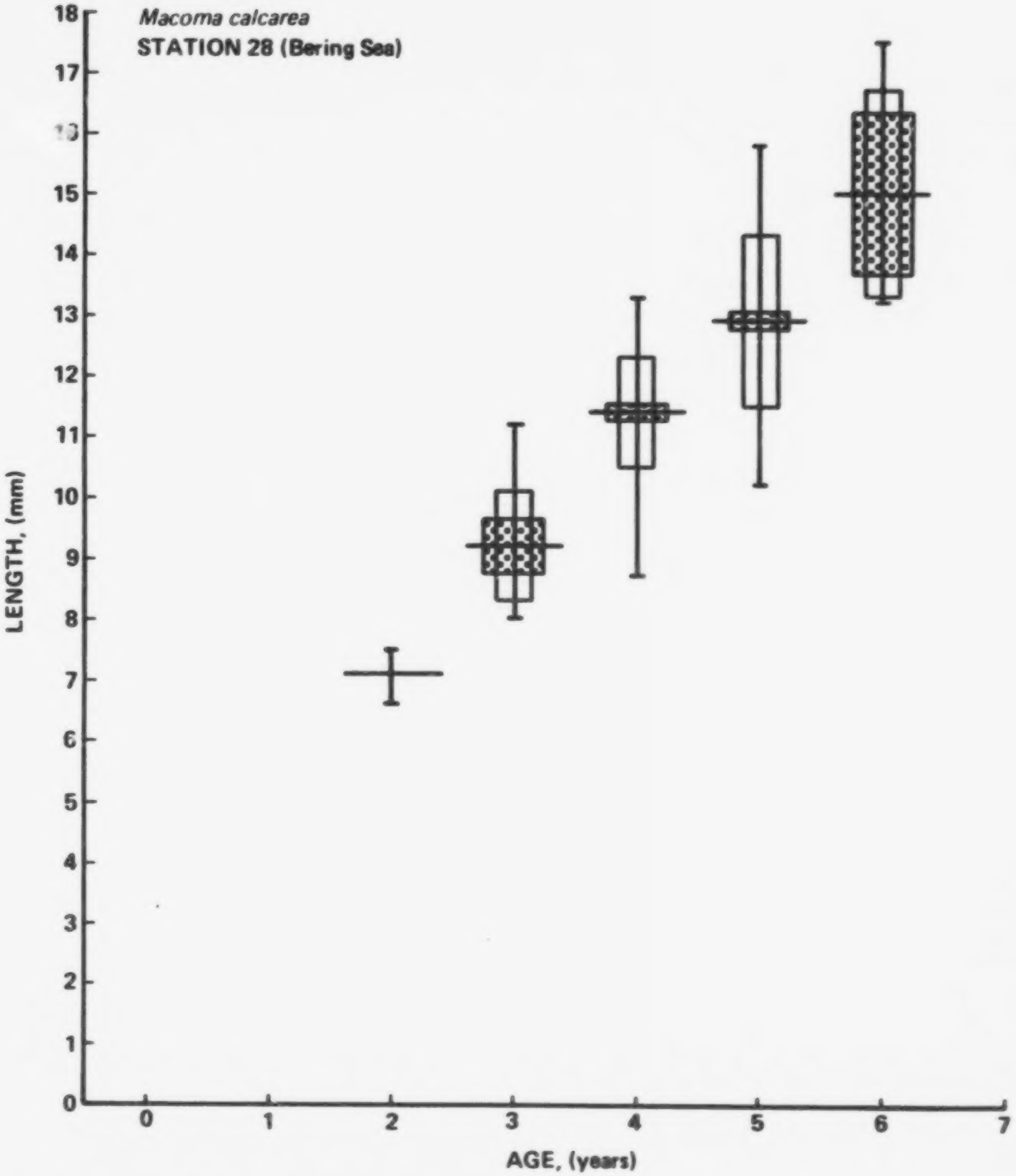


Figure 5.30. The relationship between shell length (mm) and age of *Macoma calcarea* at Station 28 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

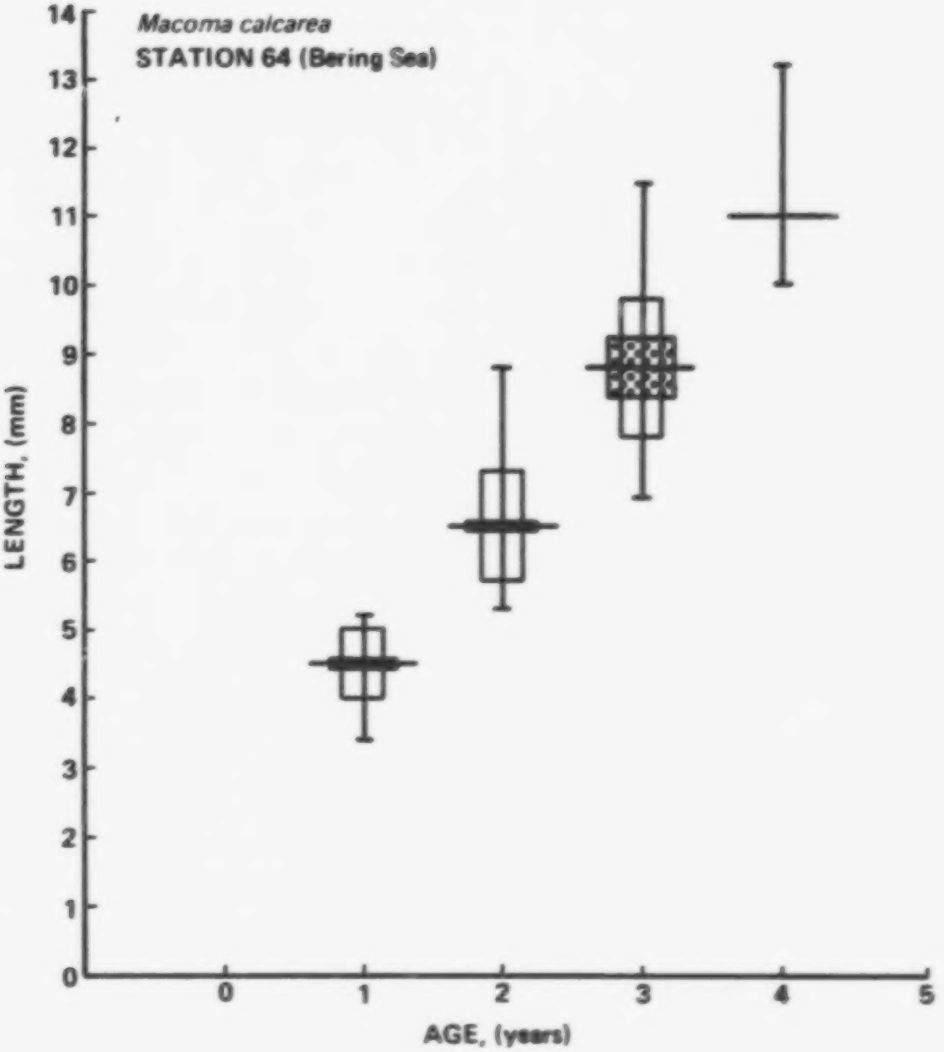


Figure 5.31. The relationship between shell length (mm) and age of *Macoma calcarea* at Station 64 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

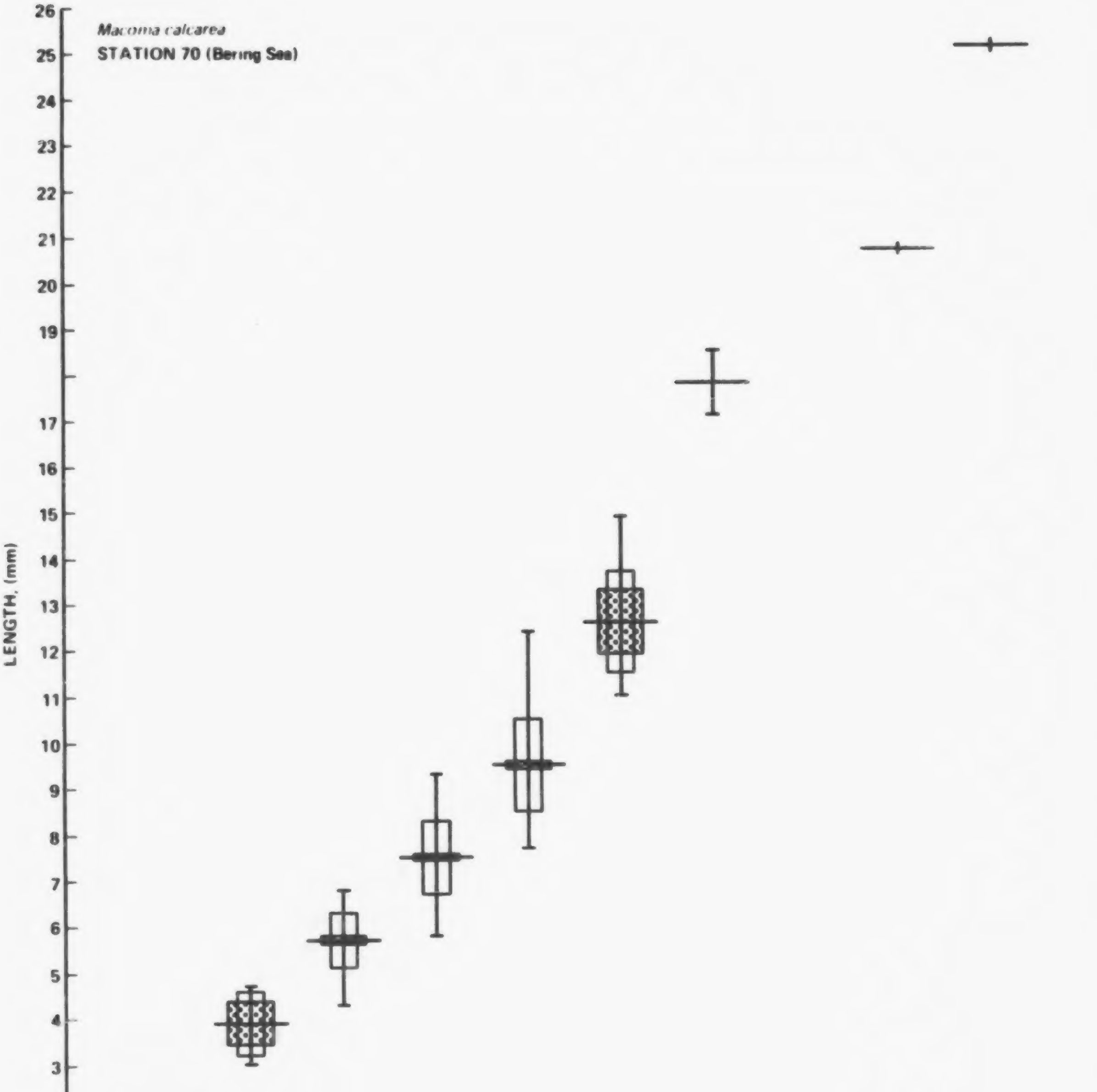


Figure 5.32. The relationship between shell length (mm) and age of *Macoma calcarea* at Station 70 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

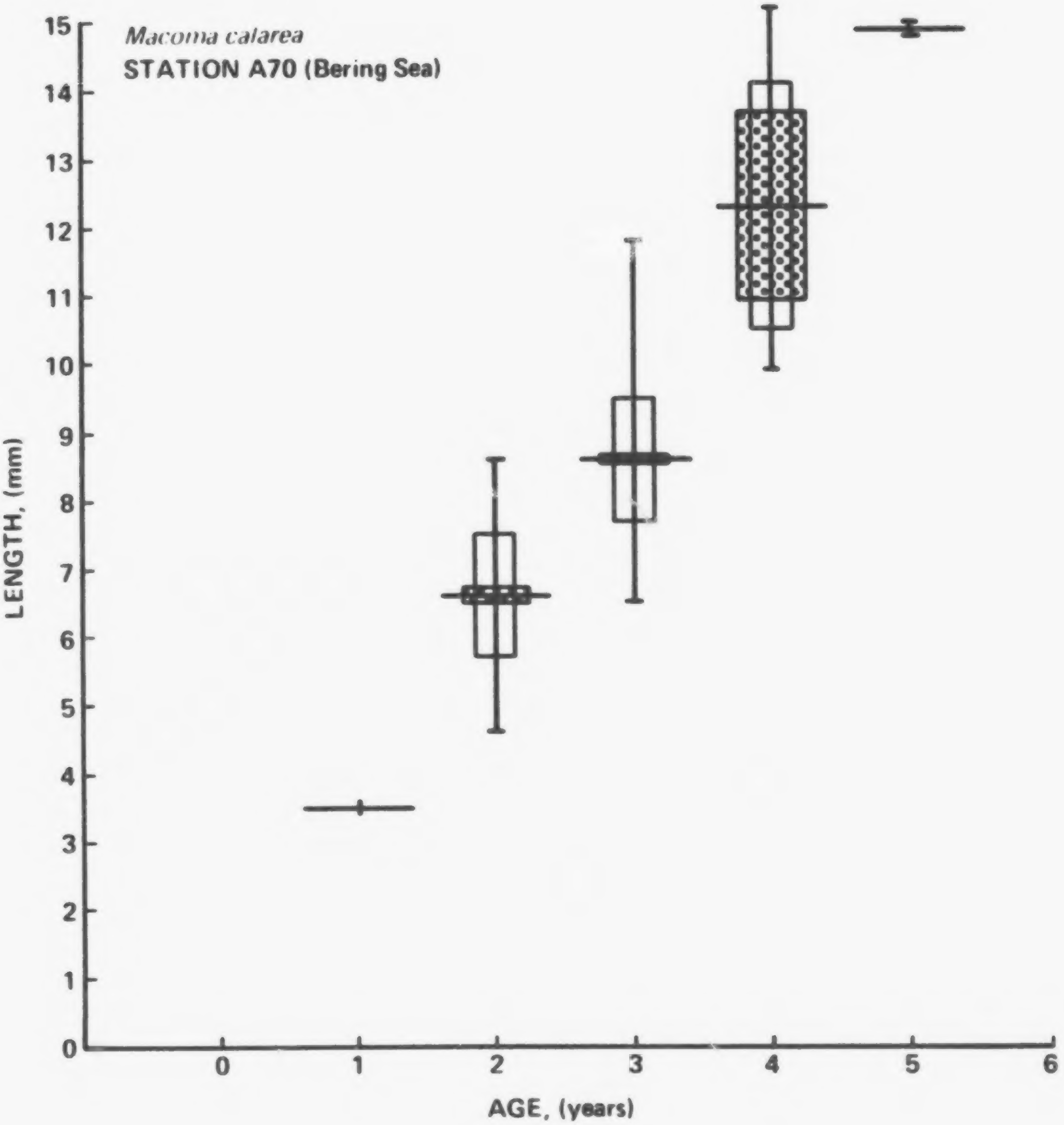


Figure 5.33. The relationship between shell length (mm) and age of *Macoma calcarea* at Station A70 in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

TABLE 5.XXXVIII

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM STATION 28 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	0	--	--	--	--
2	2	7.1	0.6	1.31	6.6 - 7.5
3	16	9.2	0.9	0.46	8.0 - 11.2
4	61	11.4	0.9	0.12	8.7 - 13.3
5	96	12.9	1.4	0.14	10.2 - 15.8
6	8	15.0	1.7	1.32	13.2 - 17.5
Total	= 183				

TABLE 5.XXXIX

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM STATION 64 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	35	4.5	0.5	0.09	3.4 - 5.2
2	171	6.5	0.8	0.06	5.3 - 8.8
3	25	8.8	1.0	0.42	6.9 - 11.5
4	4	11.0	1.5	1.80	10.0 - 13.2
5	0	--	--	--	--
6	0	--	--	--	--
7	0	--	--	--	--
8	0	--	--	--	--
9	0	--	--	--	--
10	0	--	--	--	--
11	1	48.8	0	0	48.8
Total	= 236				

TABLE 5.XL

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM STATION 70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	1	2.1	0	0	2.1
1	9	3.9	0.7	0.49	3.0 - 4.7
2	37	5.7	0.6	0.09	4.3 - 6.8
3	109	7.5	0.8	0.07	5.8 - 9.3
4	127	9.5	1.0	0.09	7.7 - 12.4
5	12	12.6	1.1	0.70	11.0 - 14.9
6	2	17.8	1.0	2.04	17.1 - 18.5
7	0	--	--	--	--
8	1	20.7	0	0	20.7
9	1	25.1	0	0	25.1
Total	= 299				

TABLE 5.XLI

THE AGE COMPOSITION AND SHELL LENGTHS OF *MACOMA CALCAREA* FROM STATION A70 IN THE EASTERN BERING SEA

N = number of clams, ML = mean shell length, SD = standard deviation, SEM = standard error of the mean, and R = range.

Year Class (Age of Clams)	N	ML (mm)	SD (mm)	SEM (mm)	R (mm)
0	0	--	--	--	--
1	1	3.5	0	0	3.5
2	76	6.6	0.9	0.11	4.6 - 8.6
3	131	8.6	0.9	0.08	6.5 - 11.8
4	8	12.3	1.8	1.39	9.9 - 15.2
5	2	14.9	0.1	0.29	14.8 - 15.0
Total	= 218				

BEST DOCUMENT AVAILABLE

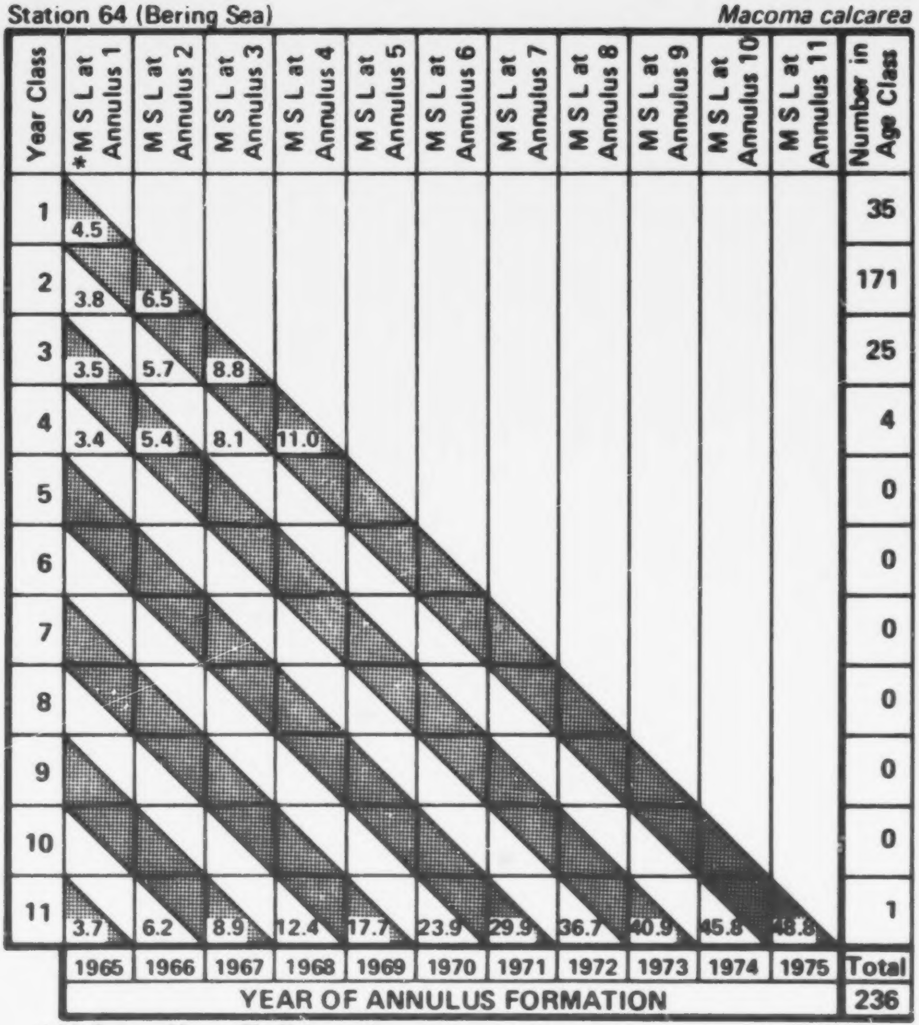
Station 28 (Bering Sea) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	Number in Age Class
1							0
2	4.2	7.1					2
3	4.0	6.7	9.2				16
4	3.8	6.1	8.8	11.4			61
5	3.5	5.8	8.4	10.5	12.9		96
6	3.3	5.4	7.6	10.2	12.5	15.0	8
	1970	1971	1972	1973	1974	1975	Total
	Y A F**						183

*M S L = Mean Shell Length, mm

**Y A F = Year of Annulus Formation

Figure 5.34. The growth history of *Macoma calcarea* from Station 28 in the southeastern Bering Sea. Mean shell length in mm.



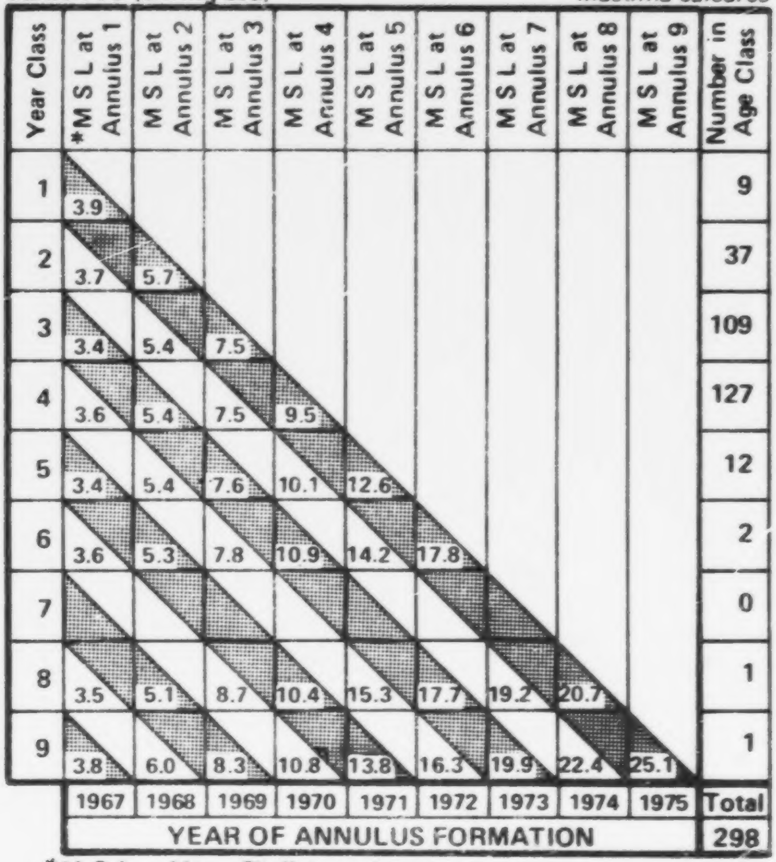
Station 64 (Bering Sea) *Macoma calcarea*

Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	M S L at Annulus 10	M S L at Annulus 11	Number in Age Class
1	4.5											35
2	3.8	6.5										171
3	3.5	5.7	8.8									25
4	3.4	5.4	8.1	11.0								4
5												0
6												0
7												0
8												0
9												0
10												0
11	3.7	6.2	8.9	12.4	17.7	23.9	29.9	36.7	40.9	45.8	48.8	1
	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION											236

*M S L = Mean Shell Length, mm

Figure 5.35. The growth history of *Macoma calcarea* from Station 64 in the southeastern Bering Sea. Mean shell length in mm.

Station 70 (Bering Sea) *Macoma calcarea*

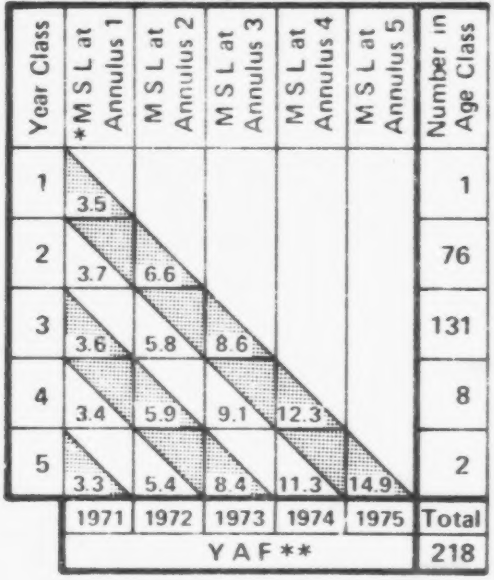


Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	M S L at Annulus 6	M S L at Annulus 7	M S L at Annulus 8	M S L at Annulus 9	Number in Age Class
1	3.9									9
2	3.7	5.7								37
3	3.4	5.4	7.5							109
4	3.6	5.4	7.5	9.5						127
5	3.4	5.4	7.6	10.1	12.6					12
6	3.6	5.3	7.8	10.9	14.2	17.8				2
7										0
8	3.5	5.1	8.7	10.4	15.3	17.7	19.2	20.7		1
9	3.8	6.0	8.3	10.8	13.8	16.3	19.9	22.4	25.1	1
	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
	YEAR OF ANNULUS FORMATION									298

*M S L = Mean Shell Length, mm

Figure 5.36. The growth history of *Macoma calcarea* from Station 70 in the southeastern Bering Sea. Mean shell length in mm.

Station A70 (Bering Sea) *Macoma calcarea*



Year Class	*M S L at Annulus 1	M S L at Annulus 2	M S L at Annulus 3	M S L at Annulus 4	M S L at Annulus 5	Number in Age Class
1	3.5					1
2	3.7	6.6				76
3	3.6	5.8	8.6			131
4	3.4	5.9	9.1	12.3		8
5	3.3	5.4	8.4	11.3	14.9	2
	1971	1972	1973	1974	1975	Total
	Y A F**					218

*M S L = Mean Shell Length, mm

**Y A F = Year of Annulus Formation

Figure 5.37. The growth history of *Macoma calcarea* from Station A70 in the southeastern Bering Sea. Mean shell length in mm.

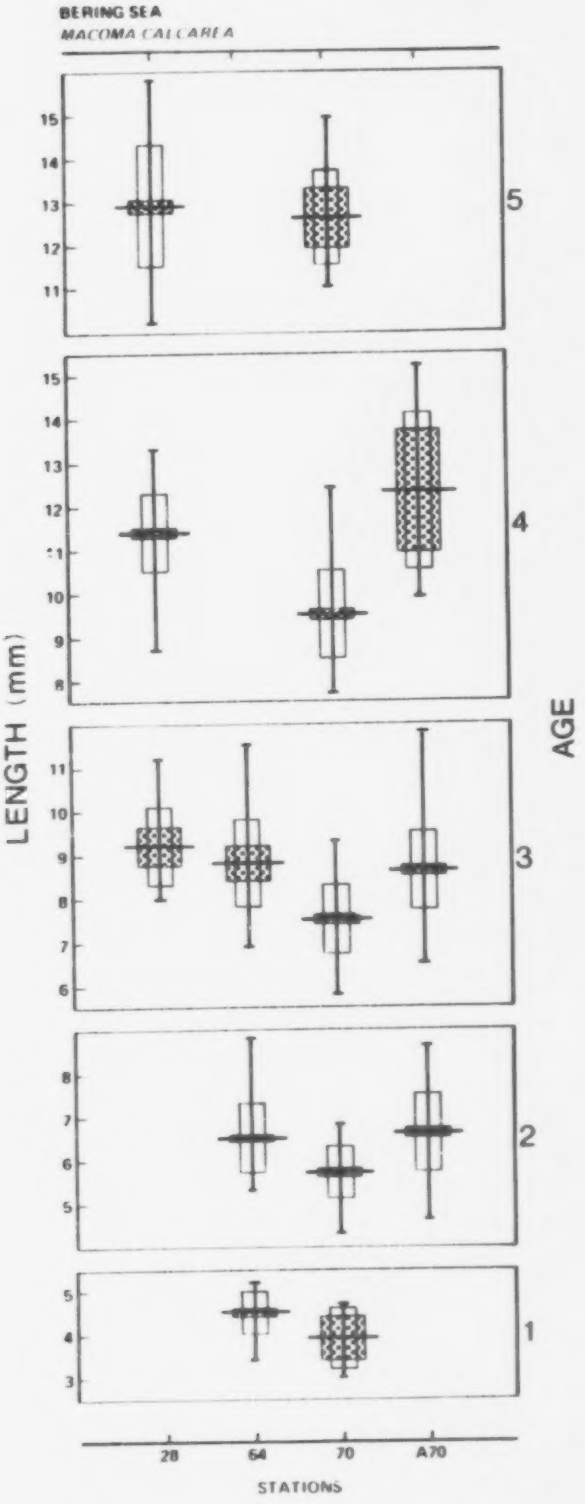


Figure 5.38. A comparison of shell length (mm) and age between four stations for *Macoma calcarea* in the southeastern Bering Sea. Mean length is denoted by the horizontal line, standard deviation by the white box, standard error of the mean by the spotted box, and range by the vertical line.

mortality estimations are restricted to age groups 2 through 11 (Table 5.XLII; Fig. 5.39). The mortality calculations (column 4 of Table 5.XLII) indicate mortality rates generally increase with age. Two-year-old individuals undergo 1.4% mortality; this rate increases to 57.2% by age 4. Only 1% of the specimens were older than 5 years, and 100% mortality occurred by age 8.

A comparison of size at age (Tables 5.XXXVI-5.XLI; Figs. 5.30-5.33) and growth histories (Figs. 5.35-5.38) for *Macoma calcarea* from the Bering Sea stations examined indicate growth rates are similar throughout the area (Tables 5.XXXVIII-5.XLI), and have been relatively stable during the period of 1965 through 1974 (Figs. 5.35-5.38). The growth rates of *M. calcarea* in the southeastern Bering Sea (Table 5.XLIII) are similar to those reported for the northeastern Bering Sea (Stoker, 1978) and Cook Inlet (Feder, 1978) with differences in mean shell lengths of the various age classes seldom exceeding 2 mm (Table 5.XLIII). The mean shell lengths of age classes 0 to 2 from outer Bristol Bay reported by Neiman (1964) are also similar to the present results; however, she observed individuals of age classes 3 to 5 to be 2.5, 6.7, and 5.0 mm larger, respectively, than those measured in the present study (Table 5.XLIII).

Annual recruitment success at the four stations examined was variable. Stoker (1978) observed similar variability in recruitment in the northern Bering Sea. He also provides mortality data for the northern Bering Sea; there he observed 50% mortality between ages 6 and 7. This compares with 50% between ages 5 and 6 in the southeastern Bering Sea (Table 5.XLII; Fig. 5.39). The longevity of another bivalve, the razer clam (*Siliqua patula*) has been shown to increase at higher latitutes (Weymouth *et al.*, 1931).

VII. GENERAL DISCUSSION

A Comparison of Species

The age structure of six species of clams from the southeastern Bering Sea has been determined, and the data for these species from all stations examined are presented in Table 5.XLIV.

TABLE 5.XLII

THE DISTRIBUTION OF *MACOMA CALCAREA* AT EACH AGE AND THE RELATIONSHIP BETWEEN AGE AND NATURAL MORTALITY

Age	Number at Age from Original Data	Number at Age from Curve Figure 39*	Natural Mortality % from Curve Figure 39*
0	1	-	-
1	45	-	-
2	286	295	1.4
3	281	291	23.7
4	200	222	57.2
5	110	95	52.6
6	10	45	100.0
7	0	0	-
8	1	0	-
9	1	0	-
10	0	0	-
11	1	0	-
Total	= 936		

*Technique of Gruffydd (1974)

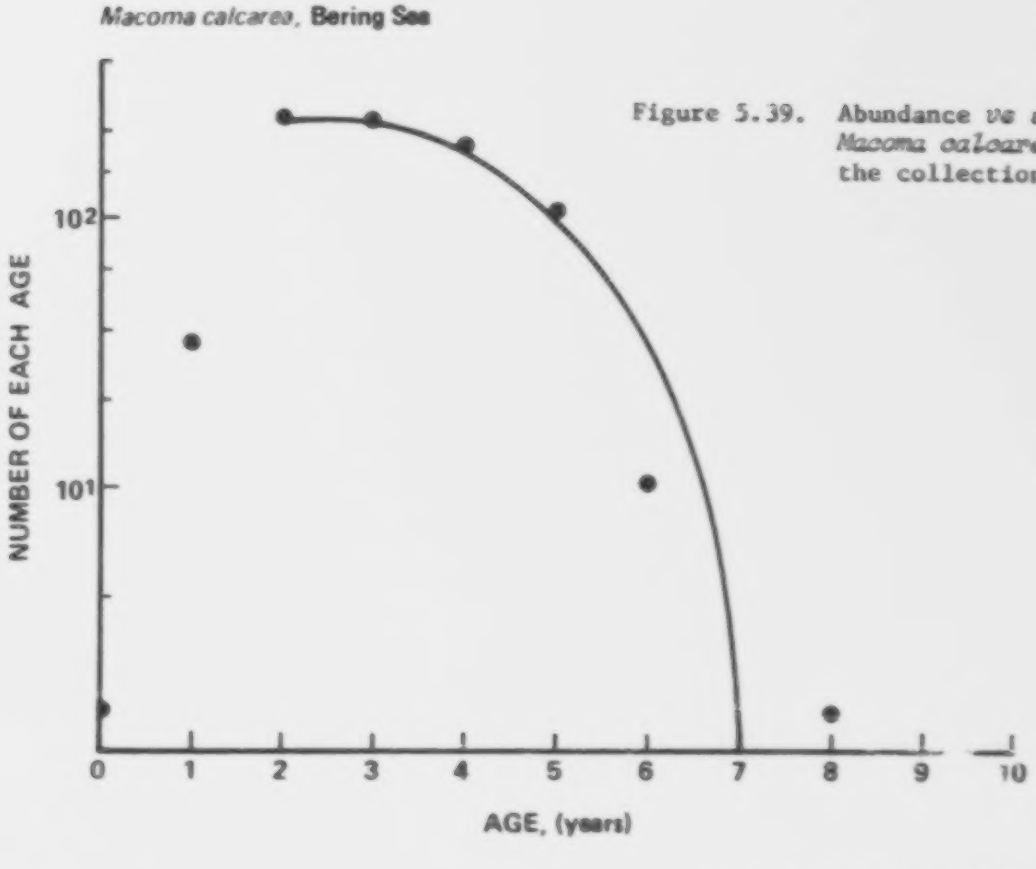


Figure 5.39. Abundance *vs* age for all *Macoma calcarea* aged in the collection.

TABLE 5.XLIII

A COMPARISON OF MEAN SHELL LENGTHS AND AGE OF *MACOMA CALCAREA* FROM FOUR STUDIES

N = number of clams and MSL = mean shell length.

Age	Bering Sea* N	Bering Sea* MSL (mm)	Bering Sea** N	Bering Sea** MSL (mm)	Bering Sea† N	Bering Sea† MSL (mm)	Cook Inlet†† N	Cook Inlet†† MSL (mm)
0	1	2.1	4	2.0			318	1.9
1	45	4.3	78	4.1			29	3.4
2	286	6.4	70	6.4			15	5.3
3	281	8.2	29	10.7			49	7.4
4	200	10.2	24	16.9	7	9.0	49	9.2
5	110	12.9	11	17.9	11	10.5	27	11.9
6	10	15.6			64	13.7	9	14.3
7	0	--			40	16.4	3	16.9
8	1	20.7			19	20.7	2	18.2
9	1	25.1			3	24.1	4	20.1
10					3	27.4	4	22.4
	Total = 935		Total = 216		Total = 147		Total = 509	

---

* Present Report

**Neiman (1964) southeastern Bering Sea

† Stoker (1978) data from six stations grouped around 61° 44'N 173° 50'W

††Feder (1978)

TABLE 5.XLIV

AGE AND MEAN SHELL LENGTHS OF SIX SPECIES OF BIVALVES FROM SEVERAL SOUTHEASTERN BERING SEA STATIONS

Age (Years)	*Nucula tenuis* (mm)	*Nuculana fossa* (mm)	*Yoldia amygdalea* (mm)	*Spisula polynyma* (mm)	*Tellina lutea* (mm)	*Macoma calcarea* (mm)
0	1.4	2.5	2.0	3.9	-	2.1
1	2.2	4.0	3.5	6.9	-	4.3
2	3.5	6.0	5.8	11.2	8.7	6.4
3	4.8	8.6	7.6	26.8	12.8	8.2
4	6.0	10.9	9.9	35.1	21.9	10.2
5	7.2	12.8	11.9	47.6	30.0	12.9
6	8.5	14.2	14.3	57.1	31.4	15.6
7	10.0	17.0	16.7	68.9	39.5	-
8	10.5	18.4	18.6	78.4	42.0	20.7
9	12.3	19.9	20.0	85.3	53.4	25.1
10			23.8	94.3	57.2	-
11			27.3	100.5	63.8	43.8
12			28.4	107.7	64.7	
13			31.1	114.0	62.8	
14				120.6	72.9	
15				123.3		
16				127.0		

General

All species of bivalves examined exhibited variable recruitment success at individual stations. However, when the age composition of clams from all stations combined (Tables 5.II, 5.XI, 5.XXIII, 5.XXVIII, 5.XXX, and 5.XXXVII) are considered, no cases of total year class failure for the study were observed. Currently, data are not available to determine the causes for recruitment success and failure in the southeastern Bering Sea. The composition by age of all six species of clams collected for this study was characterized by the occurrence of numerous older individuals (Tables 5.II, 5.X, 5.XI, 5.XXII, 5.XXIII, 5.XXVII, 5.XXX, 5.XXXVII, and 5.XLIII). Neiman (1964) observed a similar age composition for clams in the southeastern Bering Sea (Tables 5.X, 5.XX, 5.XXII, and 5.XLIII), and this contrasts with data on *Nucula tenuis*, *Macoma calcarea*, and *Spisula polynyma* from lower Cook Inlet where younger individuals predominate (Feder *et al.*, 1978a and Feder, unpub.). Neiman (1964) suggested that the large number of older individuals present in the Bering Sea indicates that predation is not a significant factor in determining bivalve mortality there. Bottom fishes appear to feed on the food benthos, inclusive of clams, on the Bering Sea shelf only when the water temperatures exceed 2°C (Neiman, 1963). Low temperatures preclude bottom fishes from feeding on the Shelf year round, and may exclude them entirely from the Shelf in cool years. However, the stomach analysis of Bering Sea snow and king crabs collected in May indicates that these predators feed on bivalves at least part of the year (Feder *et al.*, 1978b). In Cook Inlet, *N. tenuis* and *M. calcarea* are heavily preyed upon by *Chionoecetes bairdi*, *Paralithodes camtschatica*, hermit crabs, shrimps (primarily crangonids), predatody gastropods, and flat fishes throughout the year (Feder, 1978). Further study is necessary to clarify predator-prey interactions occurring in the Bering Sea.

In the six species of Bering Sea clams, variable recruitment success at individual stations and non-random distributions (Section 1) make population monitoring at specific stations impractical. However, growth rates of the species examined, as evidenced by growth histories, have been relatively stable over time. Thus, growth and growth history analyses could be used to detect changes in the environment (e.g., such as changes which may occur after an oil spill), because pre-spill growth rates could be determined by examining growth histories.

VIII. GENERAL CONCLUSIONS

See comments under Conclusions in Section 2 for comments on clams and distribution relative to sediment parameters and depth.

When the age composition of the six species of bivalve from all stations (Tables 5.II, 5.XI, 5.XXIII, 5.XXVII, 5.XXX, and 5.XXXVII) are considered, it is evident that in the southeastern Bering Sea there are no years when zero recruitment occurs. This is not the case for individual stations where the number of clams at any given age is variable. As a result of station variability, population monitoring at individual stations may not be feasible; however, use of pooled data from a number of stations should be possible. Limited data concerning recruitment or survival of other Alaskan subtidal clams are available for comparison (Feder, 1978). However, year class failures on individual beaches have been observed for the Alaskan intertidal clams *Protothaca staminea* (Paul *et al.*, 1976a) and *Saxidomus gigantea* (Paul *et al.*, 1976b). Distinct year classes, yearly growth, and growth histories of the six species of clams examined in this report were measured by the annular aging method. Measurement of growth and examination of growth histories, provides a promising technique for detecting changes in the environment which affect the growth rates of bivalves. These data are also necessary for the determination of mortality rates and secondary production.

REFERENCES

Abbott, R. T. 1974. *American seashells: The Marine Mollusca of the Atlantic and Pacific Coasts of North America.* 2nd Edition. Van Nostrand Reinhold Company. New York, N. Y. 663 p.

Alexander, V. and R. T. Cooney. 1979. Ice edge ecosystem study: Primary productivity, nutrient cycling and organic matter transfer. Final Report to NOAA, R.U. No. 427. 165 p.

Alton, M. S. 1974. Bering Sea benthos as a food resource for demersal fish populations. *In* D. W. Hood and E. J. Kelley (eds.), *Oceanography of the Bering Sea with Emphasis on Renewable Resources.* Inst. Mar. Sci., Occas. Pub. No. 2, Univ. Alaska, Fairbanks. 623 p.

Boesch, D. F., C. H. Hershner and J. H. Milgram. 1974. *Oil Spills and the Marine Environment.* Ballinger Publ. Co., Cambridge, Massachusetts. 114 p.

Chamberlin, L. J. and F. Stearns. 1963. A geographic study of the clam, *Spisula polynyma* (Stimpson). Serial Atlas of the Marine Environment, Folio 3. Amer. Geogr. Soc. 12 p.

Clifford, H. T. and W. Stephenson. 1975. *An Introduction to Numerical Classification.* Academic Press. 229 p.

Driscoll, E. G., E. D. Brandon. 1973. Mollusc-sediment relationships in northwestern Buzzards Bay, Massachusetts, U.S.A. *Malacologia* 12(1): 13-46.

Ellis, D. B. 1969. Ecologically significant species in coastal marine sediments of southern British Columbia. *Syesis* 2:171-182.

Ellson, J. G., B. Knake and J. Dassow. 1949. Report of Alaska exploratory fishing expedition, fall of 1948, to northern Bering Sea. *U.S. Fish and Wildl. Serv., Fishery Leafl.* 369:56.

Fay, F. H., H. M. Feder and S. W. Stoker. 1977. The role of the Pacific walrus in the trophic system of the Bering Sea. Report to Marine Mammal Comm. (in press).

Feder, H. J. 1976. Distribution, abundance, diversity, and productivity of benthic organisms in the Bering Sea. Annual Report to NOAA, R.U. No. 5/303. 208 p.

Feder, H. M. 1977. Distribution, abundance, diversity, and the biology of benthic organisms in the Gulf of Alaska and the Bering Sea. Annual Report to NOAA, R.U. No. 281/5/303. 340 p.

Feder, H. M. 1978. Distribution, abundance, community structure, and trophic relationships of the nearshore benthos of the Kodiak Shelf, Cook Inlet, northeast Gulf of Alaska, and the Bering Sea. Annual Report to NOAA, R.U. No. 281/5/303. 340 p.

Feder, H. M. and S. C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea and Kotzebue Sound. Inst. Mar. Sci. Report R78-1, Univ. Alaska, Fairbanks. 131 p.

Feder, H. M. and S. C. Jewett. In press. Survey of the epifaunal invertebrates of the southeastern Bering Sea with notes on the feeding biology of selected species. Inst. Mar. Sci. Report R78-5, Univ. Alaska, Fairbanks.

Feder, H. M. and G. M. Matheke. 1979. Distribution, abundance, community structure, and trophic relationships of the benthic infauna of the northeast Gulf of Alaska. Final Report to NOAA, R.U. No. 5. 247 p.

Feder, H. M. and G. Mueller. 1975. Environmental assessment of the northeast Gulf of Alaska: Benthic biology. First year Final Report to the National Oceanic and Atmospheric Administration. 200 p.

Feder, H. M. and G. J. Mueller. 1977. Bibliography of northern marine waters with emphasis on benthic organisms. Final Report to NOAA, R.U. No. 281/301. 3408 p.

Feder, H. M., G. J. Mueller, M. Dick and D. Hawkins. 1973. Preliminary benthos survey. *In* D. W. Hood, W. E. Shields and E. J. Kelley (eds.), *Environmental Studies of Port Valdez*. Inst. Mar. Sci., Occas. Pub. No. 3, Univ. Alaska, Fairbanks. 495 p.

Feder, H. M., G. J. Mueller, S. C. Jewett, M. Hoberg and K. E. Haflinger. 1976a. Environmental assessment of the Bering Sea: Benthic biology. Annual Report to NOAA, No. 5/303. 210 p.

Feder, H. M., G. J. Mueller, G. M. Matheke and S. C. Jewett. 1976b. Environmental assessment of the Gulf of Alaska: Benthic biology. Second year Annual Report to NOAA, R.U. No. 281. 176 p.

Feder, H. M., A. J. Paul, and J. M. Paul. 1976c. Growth and size-weight relationships of the pinkneck clam, *Spisula polynyma*, in Hartney Bay, Prince William Sound, Alaska. Proc. Nat. Shellfish Assoc. 66:21-25.

Feder, H. M., K. E. Haflinger, J. H. Hilsinger, M. Hoberg, S. C. Jewett, G. M. Matheke and G. J. Mueller. 1977. Distribution, abundance, diversity, and the biology of benthic organisms in the Gulf of Alaska and the Bering Sea. OCSEAP Annual Report. pp. 366-712.

Feder, H. M. S. C. Jewett, M. Hoberg, A. J. Paul, J. McDonald, G. M. Matheke and J. Rose. 1978a. Distribution, abundance, community structure, and trophic relationships of the nearshore benthos of the Kodiak shelf, Cook Inlet, northeast Gulf of Alaska and the Bering Sea. Annual Report to NOAA, R.U. No. 281/5/303. pp. 416-730.

Feder, H. M., A. J. Paul and J. M. Paul. 1978b. The pinkneck clam, *Spisula polynyma* in the eastern Bering Sea: growth, mortality, recruitment and size at maturity. Inst. Mar. Sci. Rept. R78-2, Univ. Alaska, Fairbanks, Sea Grant Report 78-2. 26 p.

Feder, H. M., J. Hilsinger, M. Hoberg, S. C. Jewett and J. Rose. 1978c. Survey of the epifaunal invertebrates of the southeastern Bering Sea. Final Report to NOAA, R.U. No. 5. 126 p.

Feder, H. M., M. Hoberg, and S. C. Jewett. 1979. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of the Kodiak shelf. Annual Report to NOAA, R.U. No. 5. 113 p.

Fenchel, T. 1969. The ecology of the marine microbenthos. 4. Structure and function of the benthic ecosystem, its chemical and physical factors and the microfaunal communities with special reference to the ciliated Protozoa. *Ophelia* 6:1-182.

Feniuk, V. F. 1945. Analysis of stomach contents of king crab. Izvestiya. Tikhookeansky Institut Rybnogo Khozyaystva. Vol. 19, pp. 17-18. (Transl. from Russian by Leda Sagen, Natl. Mar. Fish. Serv.)

Filatova, Z. A. and N. G. Barsanova. 1964. Communities of benthic fauna in the western Bering Sea. *Tr. Inst. Okeanol.* 69:6-97.

Fishery Market News. 1942. The Alaskan king crab. *Fishery Market News* 4(5a):107.

Folk, R. L. 1974. *Petrology of Sedimentary Rocks.* Hemphill Publishing Co. pp. 25-26.

Folk, R. L. and W. C. Ward. 1957. Brazos River Bar - a study in the significance of grain-size parameters. *J. Sedimentary Petrology* 27:3-26.

Franz, D. 1976. Benthic molluscan assemblages in relation to sediment gradients in northeastern Long Island Sound, Connecticut. *Malacologia* 15(2):377-399.

Gruffydd, L. L. D. 1974. An estimate of natural mortality in an unfished population of the scallop, *Pecten maximus* (L.). *J. Cons. Int. Explor. Mer* 35(2):209-210.

Hoflinger, K. E. 1978. A numerical analysis of the distribution of the benthic infauna of the southeastern Bering Sea shelf. M.S. Thesis, Univ. Alaska, Fairbanks. 136 p.

Hebard, J. F. 1959. Currents in southeastern Bering Sea and possible effects upon king crab larvae. U.S. Fish and Wildl. Serv., Special Scientific Report, Fisheries No. 293. IV and 11 p.

Hood, D. W. 1973. PROBES: A prospectus on processes and resources of the Bering Sea shelf, 1975. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 71 p.

Hoskin, C. M. 1975. Sediment data - NOAA *Discoverer*, eastern Bering Sea. Unpublished data. 8 p.

Hoskin, C. M. 1977. Macrobenthos from three fjords in western Prince William Sound, Alaska. Inst. Mar. Sci. Report R77-1, Univ. Alaska, Fairbanks. 28 p.

Hoskin, C. M. 1978. Benthos-sedimentary interactions. Annual Report to NOAA. R.U. No. 290. 57 p.

Hoskin, D. M., D. C. Burrell and G. R. Freitag. 1976. Suspended sediment dynamics in Queen Inlet, Glacier Bay, Alaska. *Mar. Sci. Comm.* 2:75-108.

Hubbs, C. L. and C. Hubbs. 1953. An improved graphical analysis and comparison of series of samples. *Systematic Zoology* 2:49:56.

Hughes, S. 1977. Results of an industry-government joint venture on the Bering Sea clams, September 1976. U.S. Department of Commerce. Northwest and Alaska Fisheries Center; National Marine Fisheries Service, NOAA. 16 p.

Hughes, S. E., R. W. Nelson and R. Nelson. 1977. Initial assessment of the distribution, abundance, and quality of subtidal clams in the southeastern Bering Sea. A Cooperative Industry-Federal-State of Alaska Study. 43 p.

Jewett, S. C. and H. M. Feder. In press. Autumn food of the starry flounder, *Platichthys stellatus*, from the northwestern Bering Sea and the Southeastern Chukchi Sea. *J. Cons. Int. Explor. Mer.*

Karinen, J. F. and S. D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting tanner crabs, *Chionoecetes bairdi*. *Mar. Fish. Rev.* 36(7): 31-37.

Kauwling, T. J. and G. J. Bakus. 1979. Effects of hydraulic clam harvesting in the Bering Sea. Final Report to North Pacific Management Council. 183 p.

Kuznetsov, A. P. 1964. Distribution of benthic fauna in the western Bering Sea by trophic zones and some general problems of trophic zonation. *Trudy Institute Okeanologii*. 69:98-177.

Lewis, J. R. 1970. Problems and approaches to baseline studies in coastal communities. FAO Technical Conference on Marine Pollution and its Effect on Living Resources and Fishing. FIR:MP 70/3-22. 7 p.

Lie, U. 1968. A quantitative study of benthic infauna in Puget Sound, Washington, U.S.A., in 1963-1964. *Fisk, Dir. Skr. (Ser. Havunders.)* 14:223-356.

Lisitsyn, A. P. 1966. Recent sedimentation in the Bering Sea (in Russian). Izd. Nauka, Moscow (Transl., 1969, avail. Nat. Tech. Inf. Serv., Springfield, Virginia, TT68-50315). 584 p.

Lloyd, M., J. H. Zar and J. R. Karr. 1968. On the calculation of information theoretical measures of diversity. *Am. Midl. Nat.* 79:257-272.

Longhurst, A. R. 1964. A review of the present situation in benthic synecology. *Bull. Inst. Oceanogr., Monaco* 63:1-54.

Lowry, L. and J. Burns. 1976. Trophic relationships among ice inhabiting phocid seals. Quarterly Report to NOAA, R.U. No. 232. 16 p.

Lowry, L. F., K. J. Frost and J. J. Burns. In press, a. Geographical and seasonal variability in the diet of ringed seals (*Phoca hispida* Schreber) in Alaska. *J. Fish. Res. Bd. Canada.*

Lowry, L. F., K. J. Frost and J. J. Burns. In press, b. Potential resource competition in the southeastern Bering Sea: Fisheries and phocid seals. *In* Proceedings of the 29th Alaska Science Conference, Fairbanks, Alaska. 15-17 August 1978.

Matheke, G. M., H. M. Feder and G. J. Mueller. 1976. Numerical analysis of the benthic infauna in the northeastern Gulf of Alaska, 432-488. *In* Proceedings of the 27th Alaska Science Conference, Fairbanks, Alaska.

McLaughlin, P. A. 1963. Survey of the benthic invertebrates fauna of the eastern Bering Sea. U.S.F.W.S. Special Scientific Report, Fisheries No. 401. 75 p.

McLaughlin, P. A. and J. Hebard. 1961. Stomach contents of the Bering Sea king crab. *Int. North Pacific Fish. Comm. Bull.* 5:5-8.

Merriam, C. H. (ed.). 1904. *Harriman Alaska Expedition.* Doubleday, Page, and Company. New York.

Mueller, G. J. 1975. A preliminary taxon list and code for ADP processing. Sea Grant Proj. A/77-02. 159 p.

Mueller, G. J., A. S. Naidu, and D. Schamel. 1976. Background benthic studies of the Torch Bay-Dixon Harbor area of the Glacier Bay National Monument. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 100 p.

Neiman, A. A. 1960. Quantitative distribution of benthos in the eastern Bering Sea (in Russian). *Zool. Zhur.* 39:1281-1292. (Transl. 402, U.S. Naval Oceanogr. Office, 1968.).

Neiman, A. A. 1963. Quantitative distribution of benthos and food supply of demersal fish in the eastern part of the Bering Sea. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48. (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Tybn, Khoz. Okeanogr. 50): 145-205. (Transl. from Russian by Israel Prog. Sci. Transl., Jerusalem, as Soviet Fish. Inv. Northeast Pacific. Part I. pp. 143-217. Avail. Natl. Tech. Inf. Serv., Springfield, Virginia, as TT67-51203.)

Neiman, A. A. 1964. Age of bivalve mollusks and the utilization of benthos by flatfishes in the southeastern Bering Sea. *In* Soviet Fisheries Investigations in the Northeast Pacific, Part 3, pp. 191-196.

Nelson-Smith, A. 1973. *Oil Pollution and Marine Ecology.* Paul Elek (Scientific Books) Ltd., London. 260 p.

Nelson, G. H., D. M. Hopkins and D. W. Schell. 1972. Cenozoic sedimentary and tectonic history of the Bering Sea. *In* D. W. Hood and E. J. Kelley (eds.), *Oceanography of the Bering Sea*, Inst. Mar. Sci. Occas. Pub. No. 2, Univ. Alaska, Fairbanks. 623 p.

Odum, E. P. 1975. *Ecology.* Holt, Rinehart, and Winston, New York. 244 p.

Olson, T. A. and F. J. Burgess (eds.). 1967. *Pollution and Marine Ecology.* Interscience, New York. 364 p.

Paul, A. J., and H. M. Feder. 1973. Growth, recruitment, and distribution of the littleneck clam, *Protothaca staminea*, in Galena Bay, Prince William Sound, Alaska. *Fish. Bull.* 71(3):665-677.

Paul, A. J., J. M. Paul and H. M. Feder. 1976a. Recruitment and growth in the bivalve, *Protothaca staminea*, at Olsen Bay, Prince William Sound, ten years after the 1964 earthquake. *The Veliger* 18(4):385-392.

Paul, A. J., J. M. Paul and H. M. Feder. 1976b. Age, growth and recruitment of the butter clam, *Saxidomus gigantea*, on Porpoise Island, Southeast Alaska. Proc. Natl. Shellfish Assoc. 66:26-28.

Pearson, E. A., P. N. Storrs and R. E. Selleck. 1967. Some physical parameters and their significance in marine waters disposal. *In* T. A. Olson and F. J. Burgess (eds.), *Pollution and Marine Ecology.* Interscience, New York. 364 p.

Pearson, T. H. 1971. Benthic ecology of Loch Linnhe and Loch Eil, a sea loch system on the west coast of Scotland. III. The effect on the benthic fauna of the introduction of pulp mill effluent. *J. Exp. Mar. Biol. Ecol.* 6:211-233.

Pearson, T. H. 1972. Effect of industrial effluent from pulp and paper mills on the marine benthic environment. *Proc. Roy. Soc. London B.* 130:469-485.

Pearson, T. H. 1975. Benthic ecology of Loch Linnhe and Loch Eil, a sea loch system on the west coast of Scotland. IV. Changes in the benthic fauna attributable to organic enrichment. *J. Exp. Mar. Biol. Ecol.* 20:1-41.

Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanogr. Mar. Biol. Ann. Rev.* 16:229-316.

Pereyra, W. T., J. E. Reeves, R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Northwest Fisheries Center Processed Report. 619 p.

Pettijohn, F. J. 1957. *Sedimentary Rocks*. 2nd edition. Harper and Row Inc., New York. pp. 27-30.

Rasmussen, E. 1973. Systematics and ecology of the Isefjord marine fauna. *Ophelia* 11(1-2):1-495.

Rees, E. I. S., A. Nicholaidow and P. Laskaridow. 1977. The effects of storms on the dynamics of shallow water benthic organisms. *In* B. F. Keegan, P. O. Ceidigh and P. J. S. Boaden (eds.), European Marine Biology Symposium, 11th, Galway, Ire., 1976. pp. 465-474.

Rhoads, D. C. 1974. Organism-sediment relations on the muddy sea floor. *Oceanogr. Mar. Biol. Ann. Rev.* 12:263-300.

Ritchie, T. P. 1977. A comprehensive review of the commercial clam industries in the United States. U.S. Dept. Comm. NOAA, NMFS, Washington, D. C.

Rosenberg, R. 1973. Succession in benthic macrofauna in a Swedish fjord subsequent to the closure of a sulphite pulp mill. *Oikos* 24:244-258.

Rowland, R. W. 1973. Benthic fauna of the northern Bering Sea. Open File Report, 1973, U.S. Geological Survey, Menlo Park, California.

Sanders, H. L. 1958. Benthic studies in Buzzards Bay. I. Animal-sediment relationships. *Limnology and Oceanography* 3(3):245-258.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay. II. The structure of the shelf-bottom community. *Limnology and Oceanography* 5(2):138-153.

Semenov, V. N. 1964. Quantitative distribution of benthos on the shelf of the southeastern Bering Sea (Bristol Bay, Alaska, Peninsula Coast, and Unimak Island). *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific*, Part III. Israel Prog. Scient. Transl., 1968. pp. 167-175.

Sharma, G. D. 1972. Contemporary depositional environment of the eastern Bering Sea: Part I -- Contemporary sedimentary regimes of the eastern Bering Sea. *In* D. W. Hood and E. J. Kelley (eds.), *Oceanography of the Bering Sea*, Inst. Mar. Sci., Occas. Pub. No. 2, Univ. Alaska, Fairbanks. 623 p.

Sharma, G. D. 1975. Contemporary epicontinental sedimentation and shelf grading in the southeast Bering Sea. *In* R. B. Forbes (ed.), *Contributions to the Geology of the Bering Sea Basin and Adjacent Regions.* Geological Society of America Special Paper 151. pp. 33-48.

Sharma, G. D., A. S. Naidu and W. Hood. 1972. Bristol Bay: A model contemporary graded shelf. *Amer. Ass. Petrol Geol. Bull.* 56(10):2000-2012.

Shevtsov, V. V. 1964. Quantitative distribution and trophic groups of benthos in the Gulf of Alaska. *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific*, Part III. Israel Prog. Scient. Transl., 1968. pp. 150-166.

Shubnikov, D. A. and L. A. Lisovenko. 1961. Data in the biology of rock sole of the southeast Bering Sea. *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific*, Part II. Israel Prog. Scient. Transl., 1968. pp. 220-226.

Skalkin, V. A. 1960. Diet of flatfishes in the southeastern Bering Sea. *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific*, Part I. Israel Prog. Sci. Transl., 1963. 15 p.

Smith, J. E. (ed.). 1968. *Torrey Canyon Pollution and Marine Life*. Cambridge Univ. Press, Cambridge. 196 p.

Smith, R., A. Paulson and J. Rose. 1978. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. Final Report to NOAA, R.U. No. 284. 70 p.

Snedecor, G. W. 1956. *Statistical Methods Applied to Experiments in Agriculture and Biology*. 5th Edition. Iowa State College Press, Ames. 534 p.

Sparks, A. K. and W. T. Pereyra. 1966. Benthic invertebrates of the southeastern Chukchi Sea. *In* N. J. Wilimovsky and J. N. Wolfe (eds.), *Environment of the Cape Thompson Region, Alaska*. U. S. Atomic Energy Commission. 1250 p.

Stephenson, W., W. T. Williams and S. Cook. 1974. Macrobenthos of soft bottoms in Moreton Bay (south of Peel Island). *Mem. Queensl. Mus.* 17:73-124.

Stoker, S. W. 1973. Winter studies of under-ice benthos and the continental shelf of the northeastern Bering Sea. M.S. Thesis, Univ. Alaska, Fairbanks. 60 p.

Stoker, S. 1977. Report on a subtidal commercial clam fishery proposal for the Bering Sea. Final Report to U.S. Marine Mammal Commission, Contract MM7AD-076. Univ. Alaska, Fairbanks. 33 p.

Stoker, S. 1978. Benthic invertebrate macrofauna of the eastern Continental Shelf of the Bering/Chukchi Seas. Ph.D. Dissertation, Int. Mar. Sci., Univ. Alaska, Fairbanks. 259 p.

Straughan, D. 1971. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Allan Hancock Foundation, Univ. of Southern California, Los Angeles. 425 p.

Swartz, R. C., M. S. Wass and D. F. Boesch. 1972. A taxonomic code for the biota of the Chesapeake Bay. Spec. Sci. Rept. No. 62 of the Virginia Inst. Mar. Sci. 117 p.

Takenouti, A. Y. and K. Ohtani. 1972. Current and water masses in the Bering Sea: A review of Japanese work. *In* D. W. Hood and E. J. Kelley (eds.), Oceanography of the Bering Sea, Inst. Mar. Sci., Occas. Pub. No. 2, Univ. Alaska, Fairbanks. pp. 39-57.

Takeuchi, I. 1967. Food of king crab, *Paralithodes camtschatica* off the west coast of the Kamchatka Peninsula, 1958-1964. Bull. Hokkaido Reg. Fish. Res. Lab. 28:32-44.

Thorson, G. 1957. Bottom communities (sublittoral or shallow shelf). *In* J. W. Hedgpeth (ed.), *Treatise on Marine Ecology and Peleoecology*, Vol. 1, Mem. Geol. Soc. Am. 67:461-534.

Weymouth, F. W. 1923. The life-history and growth of the Pismo clam (*Tivela stultorum* [mawe]). Calif. Fish. Game Comm., Fish Bull., 7: 120.

Weymouth, F. W., H. C. McMillan and W. H. Rich. 1931. Latitude and relative growth in the razor clam, *Siliqua patula*. *J. Exper. Biol.*, 8:228-249.

Wigutoff, N. B. and C. B. Carlson. 1950. S.S. *Pacific Explorer*, Pt. V. 1948 Operations in the North Pacific and Bering Seas.

Williams, W. T. and W. Stephenson. 1973. The analysis of three-dimensional data (sites x species x time) in marine ecology. *J. Exp. Mar. Biol. Ecol*. 11:207-227.

Yasuda, T. 1967. Feeding habit of the zuwaigani, *Chionoecetes opilio elongatus*, in Wakasa Bay. I. Specific composition of the stomach contents. *Bull. Jap. Soc. Sci. Fish.* 33(4):315-319. (Transl. from Japanese by Fish. Res. Bd. Can., Transl. Serv. No. 1111.)

Zenkevitch, La A. 1963. *Biology of the Seas of the USRR*. George Allen and Unwin. Ltd., London. 955 p.